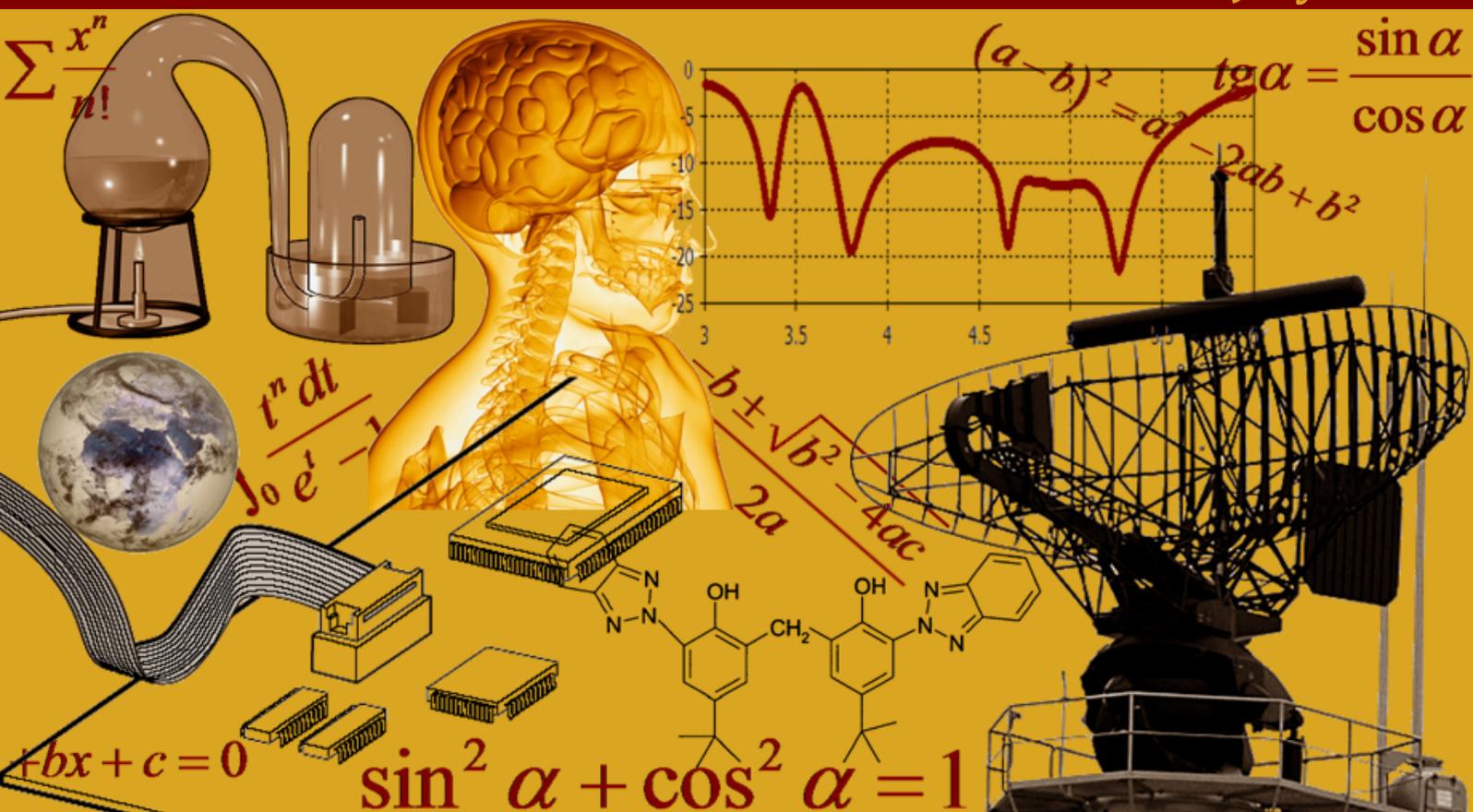


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## Évaluation d'une Antenne Patch Micro-ruban pour la Détection des Tumeurs du Sein

### [ Evaluation of a microstrip patch antenna for Breast Tumor Detection ]

*Radouane KARLI and Hassan AMMOR*

Electronic and Communication Laboratory EMI, Mohammed V University-Agdal, UM5A, Rabat, Morocco

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**ABSTRACT:** The microwave imaging is explored as an imaging modality for early detection of breast cancer. When exposed to electromagnetic waves, the breast tumor has electrical properties that are substantially different from those of healthy breast tissue. This article describes a study for the detection of breast cancer. We examine the ability to detect tumors by a microstrip patch antenna operating at a frequency of 2.45GHz. Using a simple model in the form of a cone. This model consists of the breast skin and fat and the tumor tissues. The study is done according to several distances between the patch antenna and the model of the breast. Simulation results are presented, namely, reflection coefficient, VSWR and radiation pattern of the antenna patch and the current density in the breast skin, fatty tissue and the tumor and also the distribution of magnetic field to give us a clear insight into the concept studied.

**KEYWORDS:** Microwave imaging, breast cancer, patch antenna, tumor, tissues.

**RESUME:** L'imagerie micro-ondes est explorée comme une modalité d'imagerie pour la détection précoce du cancer du sein. Lorsqu'il est exposé à des ondes électromagnétiques, la tumeur du sein présente des propriétés électriques qui sont sensiblement différentes de celles des tissus mammaires sains. Cet article décrit une étude pour la détection du cancer du sein. Nous examinons la capacité de détection des tumeurs par une antenne patch micro-ruban opérant à une fréquence de 2.45GHz. En utilisant un simple modèle de sein sous forme de cône. Ce modèle est constitué de la peau du sein et des tissus gras ainsi que la tumeur. L'étude est faite suivant plusieurs distances entre l'antenne patch et le modèle du sein. Les résultats de simulation sont présentés, à savoir ; coefficient de réflexion, ROS et diagramme de rayonnement pour l'antenne patch, ainsi, la densité de courant dans la peau du sein, tissus gras et au niveau de la tumeur et aussi la distribution du champ magnétique permettant de nous donner un aperçu clair sur le concept étudié.

**MOTS-CLEFS:** Imagerie micro-onde, cancer du sein, Antenne patch, tumeur, tissus.

### 1 INTRODUCTION

Le cancer du sein est le cancer le plus fréquent chez la femme en particulier dans les pays développés [1]. Son incidence est estimée à plus d'un million de nouveaux cas par an dans le monde ; 22% des cancers diagnostiqués chez la femme [2]. Le cancer du sein est à l'origine de 14% des décès chez les femmes, soit plus de 370 000 décès par an dans le monde [3].

En 2000, dans le monde, les cancers du sein ont représenté environ 22% de tous les nouveaux cancers des femmes constituant le premier cancer féminin, y compris dans les pays en voie de développement. On estime qu'une femme a 10% de probabilité d'être atteinte d'un cancer du sein jusqu'à l'âge de 75ans [4].

Environ 1 sur 8 (12%) des femmes dans les Etats-Unis développeront un cancer du sein invasif au cours de leur vie. L'incidence des cancers du sein est de 4 à 10 fois plus élevée dans les pays occidentaux (États-Unis et Europe du nord principalement) en comparaison avec l'Asie et avec l'Afrique [5]. La répartition de cette pathologie dans le monde est hétérogène: certains pays ont un taux annuel standardisé au-dessus de 120 tandis que pour d'autres pays, il est inférieur à 100 [6]. En Afrique, où la situation épidémiologique est encore fortement marquée par la présence des maladies transmissibles, c'est le deuxième cancer féminin après celui du col de l'utérus. Dans les pays en voie de développement, avec plus de 70% des cancers du sein qui sont diagnostiqués aux stades III et IV, la médiane de survie après le diagnostic est inférieure à cinq ans [7].

Aux États-Unis en 2013, environ 232 340 nouveaux cas de cancer invasif du sein seront diagnostiqués chez les femmes, 64 640 nouveaux cas de carcinome in situ (CIS) seront diagnostiqués et 39 620 femmes mourront du cancer du sein [8].

Au Maroc, Entre 30 et 45 mille personnes sont affectées chaque année par le cancer du sein, soit environ 36.12% [9] et semble être le 1er cancer féminin avec une incidence de 60 à 90/100 000 femmes par an.

Depuis la naissance des techniques radiologiques dans les années 1960, plusieurs méthodes ont été mises au point. Les plus fréquentes sont basées sur l'utilisation des rayons X, ultrasons et champs magnétiques.

Le développement des techniques scientifiques actuelles améliore, de jour en jour, la qualité de la santé, du travail, et de la vie de l'Homme. Le domaine de la médecine en particulier a permis une amélioration considérable. Les techniques de diagnostic médical radiologique, qui permettent de visualiser l'intérieur d'un organisme de façon non évasive, sont les exemples mêmes de ce progrès scientifique [10].

La mammographie est l'examen de référence pour le dépistage et le diagnostic du cancer du sein [11]. Ses performances sont néanmoins limitées notamment quand la densité mammaire est élevée, elles sont estimées à 82% [12].

L'imagerie du sein permet aujourd'hui non seulement la détection de lésions infra-centimétriques, mais également leur caractérisation. La détection repose encore principalement sur la mammographie, qui est le meilleur examen de dépistage du cancer du sein. L'échographie et l'IRM sont des techniques de plus en plus employées pour la caractérisation de lésions mammaires douteuses ou ambiguës. La détermination du caractère bénin ou malin d'une lésion solide en échographie se base habituellement sur des critères morphologiques: forme, échogénicité, atténuation postérieure, irrégularité des contours ou microlobulation. L'analyse des lésions mammaires en IRM est basée principalement sur des critères morphologiques (taille, forme, contours, rehaussement interne des prises de contraste), mais aussi cinétiques (rapidité, intensité, dynamique de la prise de contraste).

L'échographie mammaire complémentaire est alors recommandée en complément de la mammographie ou chez les femmes présentant un haut risque de cancer du sein, l'IRM mammaire en dépistage est alors associée à la mammographie et l'échographie.

L'IRM est une technique de diagnostic médical puissante qui fournit des images tridimensionnelles et en coupe de grande précision anatomique. C'est une technique radiologique récente, non invasive et sans effets secondaires connus, basée sur le phénomène physique de résonance magnétique nucléaire (RMN) [14]. Il s'agit simplement d'observer la résonance magnétique nucléaire (RMN) des protons de l'eau contenus dans l'organisme, c'est à dire la réponse des noyaux soumis à un champ magnétique extérieur et à une excitation électromagnétique.

L'intensité recueillie pour un élément de volume dépend de la concentration de l'eau à l'endroit considéré et on obtient ainsi une image tridimensionnelle de la répartition de l'eau dans le corps d'un patient. Selon la méthode utilisée, le contraste peut être augmenté si les temps de relaxation des spins nucléaires (décrivant le retour à l'équilibre des noyaux après l'excitation) diffèrent dans les deux zones. Il est donc possible d'observer des altérations des tissus (telles que des tumeurs) grâce aux différences de densité et de relaxation de l'eau.

En outre, le développement des antennes patchs émetteurs-récepteurs fonctionnant à 2,45GHz est connu pour réduire les données encombrées, dans un intérêt de produire des images bien localisées ou des parties réelles et imaginaires des nombres d'ondes [15]. Les interactions entre les EM et les signaux gigahertz sont principalement à l'étude pour un contraste significatif et cohérent entre les tissus mammaires malignes et d'autres [16].

Dans cet article, nous présentons la conception et la simulation de l'imagerie du sein micro-ondes utilisant le signal à 2,54GHz dans un but de localiser et caractériser les tumeurs cachés dans les seins en utilisant des ondes électromagnétiques à des fréquences micro-ondes. Un modèle de sein avec deux couches et une tumeur sous HFSS a été utilisé pour la modélisation et la simulation. Les résultats des simulations sont présentés, en montrant que le placement direct de l'antenne sur la peau du sein peut augmenter la sensibilité de détection des tumeurs via les systèmes de l'imagerie par micro-ondes.

## 2 PRINCIPE DE L'IRM

La technique d'imagerie micro-ondes du sein utilise la diffusion de signaux par un objet, lorsque celui-ci est éclairé par un signal électromagnétique. La diffusion du signal par un objet dépend de divers facteurs, dont l'environnement, la force du signal, et les propriétés du matériau. Pour une source de signal de données, le signal diffusé dépend des caractéristiques électriques de l'objet, en particulier la constante diélectrique et la conductivité. Ce principe est utilisé pour détecter les tumeurs dans le sein à l'aide des signaux micro-ondes. Les tumeurs du sein ont des propriétés électriques très distinctes (permittivité diélectrique élevée et une conductivité plus élevée), ce qui permet de les détecter en analysant les signaux diffusés. Comme le montre la figure 1, la quantité de signal diffusée par une tumeur du sein est supérieure à celle des tissus mammaires normaux. Celle-ci peut être reçue par une antenne bien localisée ou la modification de ces propriétés d'émission en raison des signaux diffusés, peuvent être analysés et utilisés pour la détection des tumeurs.

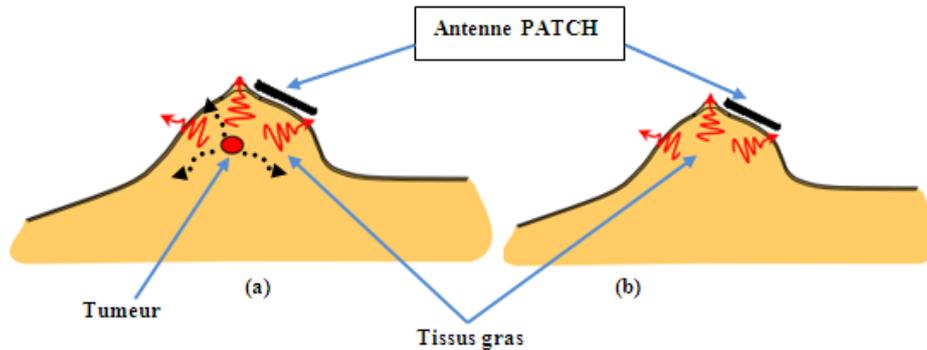


Fig. 1. Schéma représentatif du sein, antenne patch et tumeur montrant diffusion de signaux. (a) sein avec tumeur. (b) sein normal

## 3 METHODE & MODELE

Une antenne patch microruban rectangulaire conçu a été envisagée. Un substrat de type FR4\_EPOXY a été choisi comme substrat de l'antenne, ayant comme dimensions  $60 \times 70 \text{ mm}^2$  avec une constante diélectrique  $\epsilon_r = 4.4$  et une épaisseur  $H=1.58 \text{ mm}$ . Le patch rectangulaire comprend des fentes afin d'augmenter la bande passante. L'alimentation est effectuée via une ligne microstrip avec une impédance normalisée à  $50 \Omega$ . L'antenne a été optimisée pour résonner à une fréquence de  $2,45 \text{ GHz}$ .

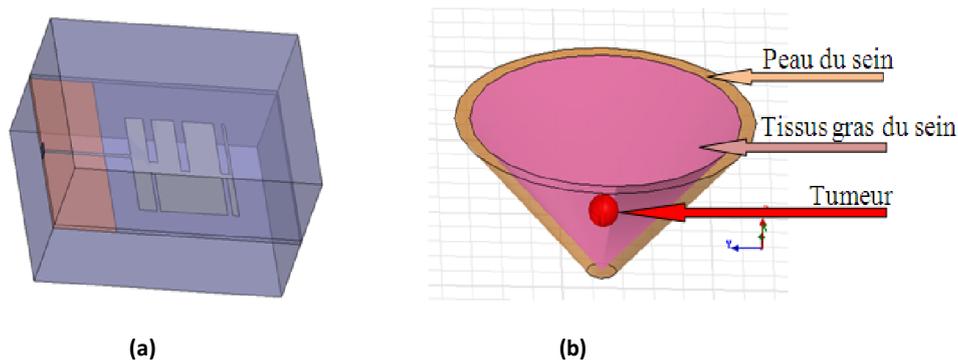


Fig. 2. (a) Schéma de l'antenne patch. (b) Modèle du sein avec tumeur

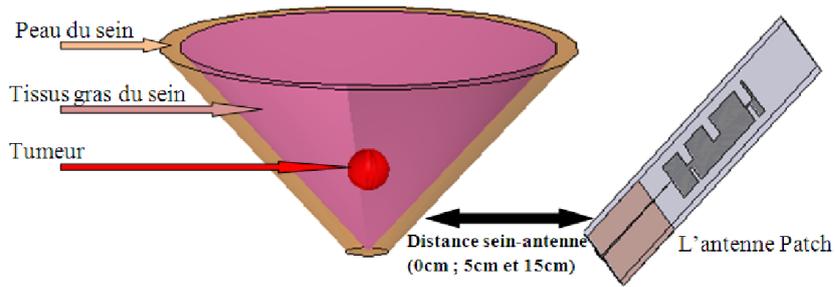


Fig. 3. Antenne placée en contact avec le sein pour différentes distances

Tableau 1. Propriétés diélectriques du model à 2.45GHz

	Conductivité $\sigma(S/m)$	Permittivité $\epsilon_r$
Peau du sein	1.1	39
Tissus gras	0.59	4.49
Tumeur	4	50

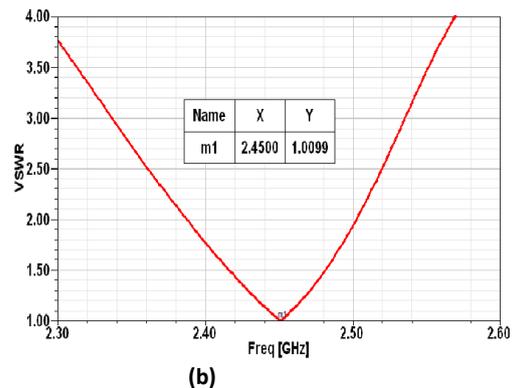
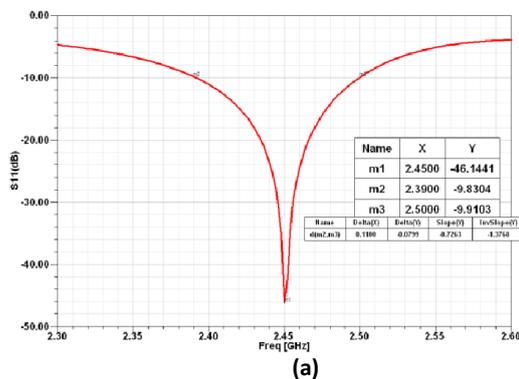
Plusieurs modèles des seins ont été utilisés par les chercheurs [17-18]. Nous avons utilisé un modèle de forme de cône avec des dimensions les plus courantes, telles que présentées dans la Figure 2(b).

Les propriétés diélectriques qui ont été utilisés sont présentées dans le tableau 1, où  $\sigma$  est la conductivité des tissus et  $\epsilon_r$  est la permittivité diélectrique. Dans la littérature [19-22] la taille de la tumeur varie de 0.2cm à environ 1.5cm ou plus. Nous avons utilisé une tumeur sphérique avec un rayon de 0.5cm [23], afin de comparer nos résultats avec d'autres travaux plus fréquent dans la littérature.

Le modèle du sein a été développé sous forme de cône composé de la peau représentant 10cm de largeur, 5cm de hauteur et une largeur de 5mm [23], le volume restant est composé des tissus gras du sein [23]. Le modèle du sein développé a été simulé, en plaçant une antenne à 15cm du sein (cas I), puis à 5cm du sein (cas II) et par suite en contact avec le sein (cas III) comme le montre la figure 3.

#### 4 RESULTATS & DISCUSSION

La figure 4 représente les divers paramètres de l'antenne optimisée à 2.45GHz; coefficient de réflexion, ROS et le diagramme de rayonnement.



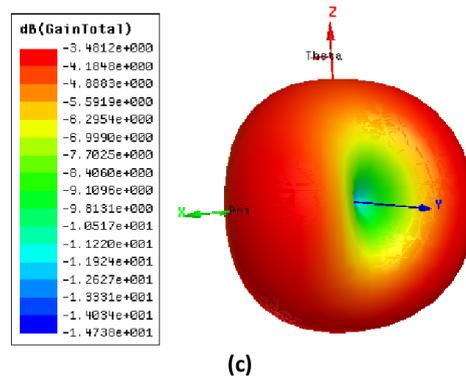


Fig. 4. (a) Coefficient de réflexion. (b) ROS. (c) Diagramme de rayonnement

Le modèle d'antenne optimisé a été utilisé pour simuler les modèles mammaires développées dans HFSS. La simulation a été effectuée pour différentes distances antenne-modèle du sein, à savoir premier cas où l'antenne est séparé de 15cm du sein (cas I, Figure 5), deuxième cas où l'antenne est séparé de 5cm du sein (cas II, Figure 6) et troisième cas où l'antenne est placé sur la surface du sein (en contact avec la peau du sein, cas III, figure 7).

Comme le signal diffusé par un objet dépend de la densité de courants induits dans cet objet, la densité de courant dans la tumeur ainsi que dans la peau du sein et les tissus gras sont comparées. Les figures 5,6 et 7 représentent respectivement les résultats de simulation des densités de courant dans la peau du sein, les tissus gras et la tumeur, pour les trois cas (15cm ; 5cm et 0cm).

Ainsi, une comparaison entre le champ magnétique dans la tumeur du sein pour les trois cas est représentée dans la figure 8.

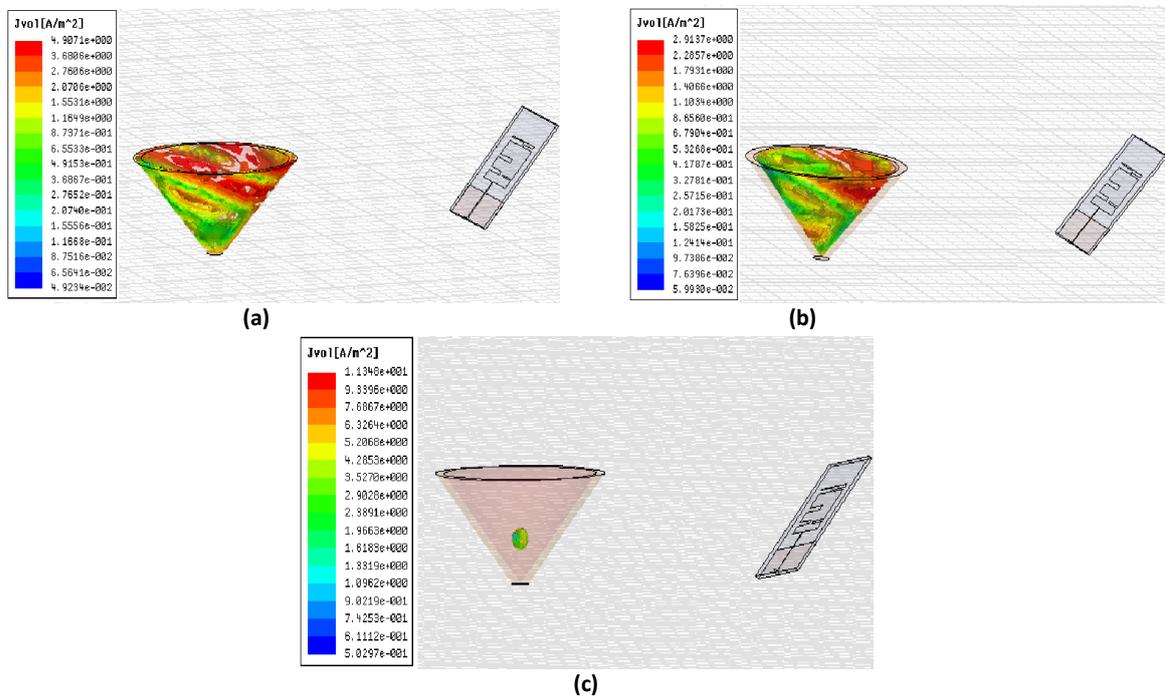


Fig. 5. Densités de courant (a) la peau, (b) les tissus gras, & (c) tumeur, lorsque l'antenne est place à 15cm du sein.

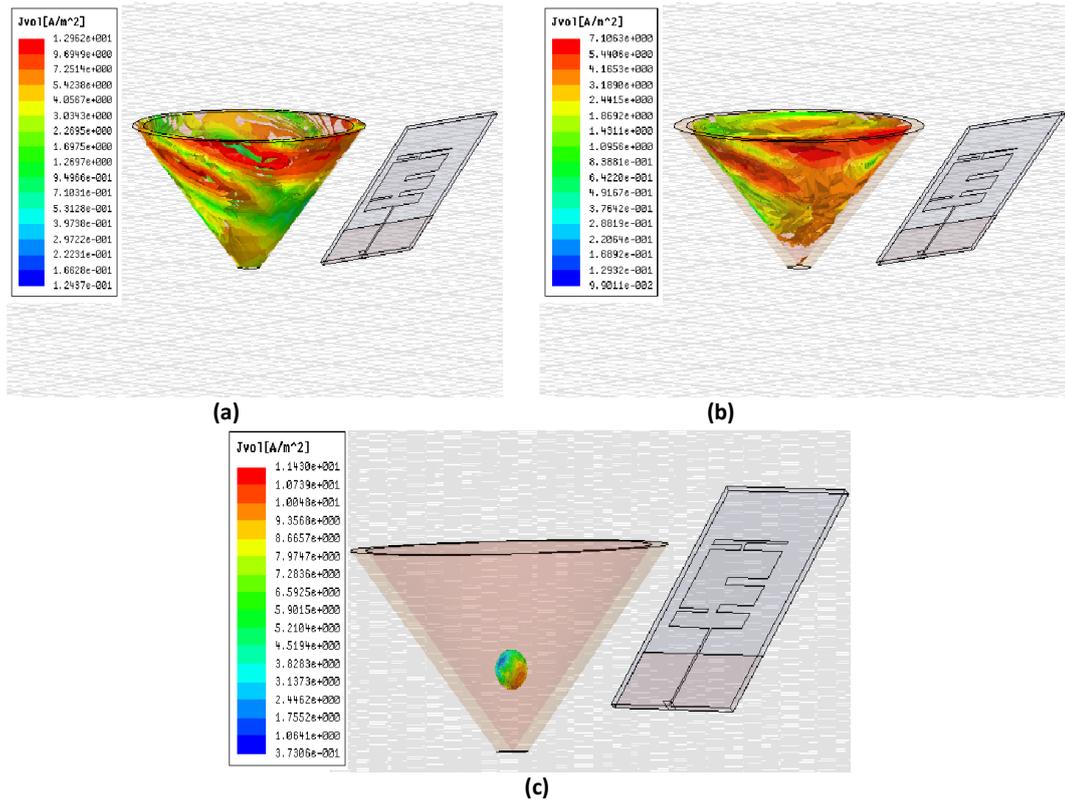


Fig. 6. Densités de courant (a) la peau, (b) les tissus gras, & (c) tumeur, lorsque l'antenne est place à 5cm du sein.

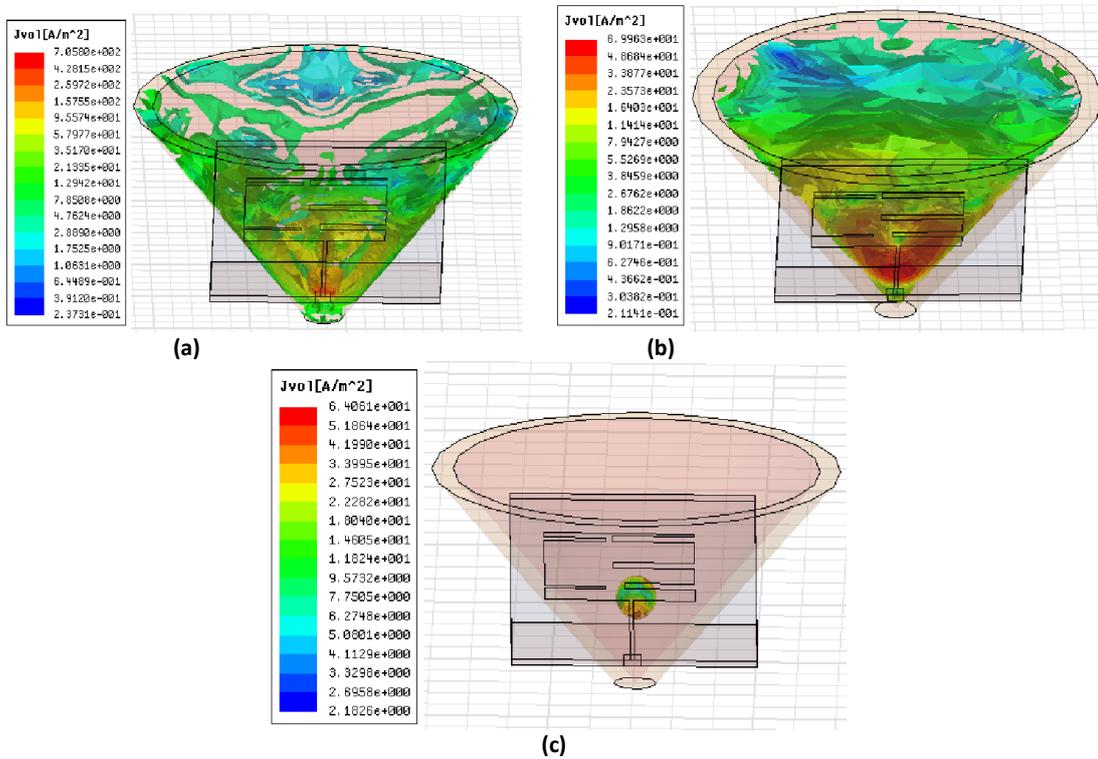


Fig. 7. Densités de courant (a) la peau, (b) les tissus gras, & (c) tumeur, lorsque l'antenne est place à 0cm du sein.

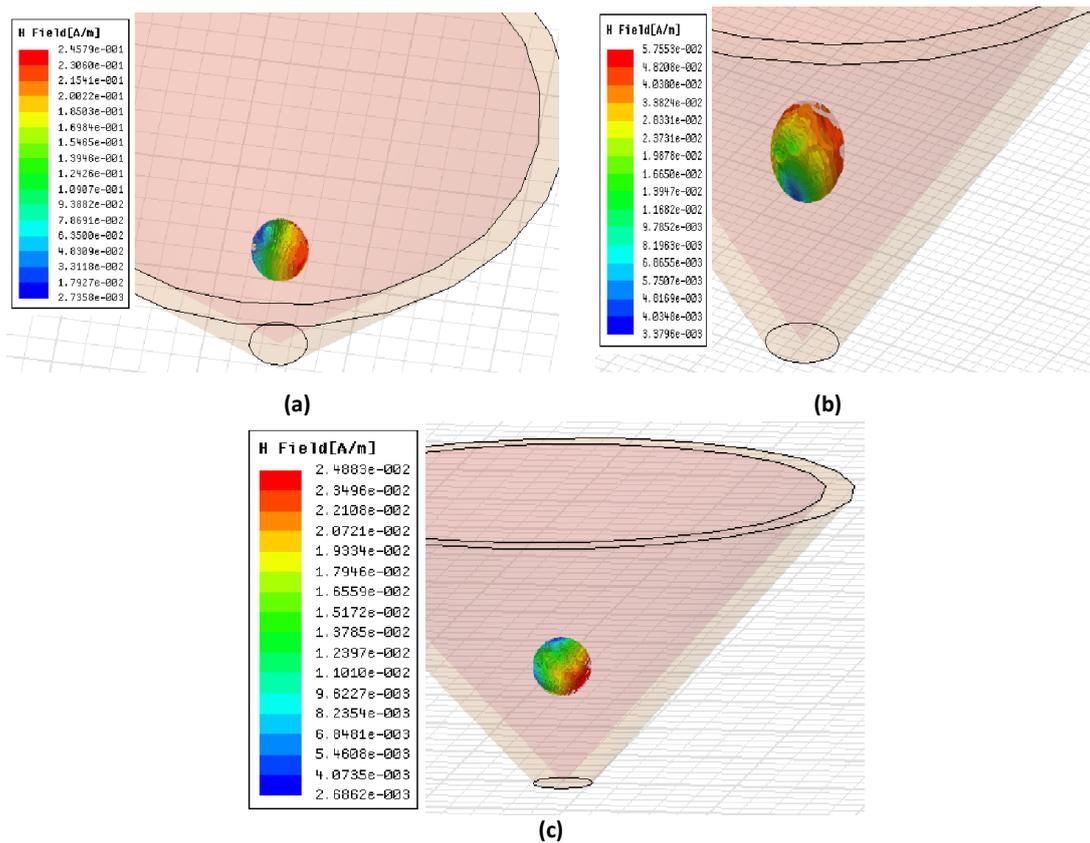


Fig. 8. Champ H dans la tumeur (a) 0cm, (b) 5cm and (c) 15cm

On constate que la densité de courant dans la tumeur dans les deux premiers cas ( $11A/m^2$ ) est environ six fois plus élevée que la densité de courant dans le premier cas ( $64A/m^2$ ), ce qui accroît la visibilité de la tumeur à l'antenne par le même facteur. Ainsi, la valeur du champ magnétique au niveau de la tumeur augmente tant que l'antenne est placée directement sur la peau du sein. Les résultats de simulation montrent que la visibilité de la tumeur ou de la sensibilité de l'antenne pour la détection de la tumeur peut être augmentée en plaçant une antenne en contact avec le sein.

## 5 CONCLUSION

Dans cet article, Une antenne patch miniature et simple qui peut être placée sur la peau du sein a été présentée. Cette antenne résonne à 2.45GHz présentant une puissance d'émission de 100mW. Ainsi, un modèle de sein a été discuté. Les modèles de simulation mis au point et les résultats présentés montrent que la sensibilité de la détection des tumeurs augmente lorsque l'antenne est en contact avec la surface du sein, par opposition à lorsqu'il est placé à une distance lointaine. Les résultats des simulations montrent que les densités de courant à l'intérieur de la tumeur est environ six fois plus élevé lorsque l'antenne est en contact avec le sein par rapport à quand il est placé à 5cm ou à 15cm du sein, aussi la valeur du champ magnétique diminue quand la distance antenne patch-sein augmente et donc cela nous fournit une preuve du concept présenté.

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## Factors Influencing SMEs' Export Performance and Marketing strategy

*Salem BEN BRAHIM*

Université de Tunis El Manar, FSEG Tunis,  
B.P 248 El Manar II,  
2092 Tunis, TUNISIE

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**ABSTRACT:** The present paper aims at identifying SMEs' export marketing strategy (EMS) and export performance (EP). A consistent interest in international marketing has been to study factors influencing SMEs' export performance. To this end, a survey of 216 Tunisian SMEs was conducted. The results indicate that technological benefits have a positive effect on SMEs adaptation, which positively affects EP. They also indicate that firm size positively relates to export growth.

**KEYWORDS:** International Marketing, Export Performance, Adaptation of Export Marketing Strategy, SMEs.

### 1 INTRODUCTION

Export is the most adapted internationalization mechanism by SMEs. Despite lack of resources, they value their flexible organizational structure that allows them to adapt themselves to the needs of foreign markets more quickly than large companies (Lages and Montgomery, 2004). One of the central questions that international marketing researchers were interested in is to explain why some SMEs are more successful than others (Navarro et al, 2010; Lages et al, 2008). Does this report to the effect of resources management mode, adaptation of an export-oriented marketing strategy or the effect of SMEs characteristics? Most of the previous studies on the topic have been conducted in developed countries (Singh, 2009). This explains our interest in studying factors influencing EMS of Tunisian SMEs. Our aim is to identify factors behind EMS and those behind exportation performance of SMEs. To this end, we developed a model that links the different variables included in previous research, using structural equations for its validation. Factors of EP are: size, age, international experience, resources, barriers, and EMS (Prasertsakul, 2013; Denicolai, Zucchella, Strange, 2014, Wu, 2013). The effect of these variables on export dimensions is captured directly (Cavusgil and Zou, 1994), and indirectly through EMS (Leonidou et al, 2002).

### 2 THEORETICAL FRAMEWORK, RESEARCH HYPOTHESES AND CONCEPTUAL MODEL

Lado et al. (2004) argue that research on EMS relies among others on source-based paradigm and the contingency approach. The approach resources states that it is company's resources and expertise that are responsible for its competitive advantage. This approach sees the company as a combination of resources whose attributes and nature determine its strategy and performance (Navarro et al, 2010). The literature review shows, first, that the most cited factors of EP are size, age, international experience and resources, the barriers encountered in foreign markets, and adaptation of EMS (Aaby and Slater, 1989). Second, the effect of these variables on EP is captured either directly (Cavusgil and Zou, 1994), or indirectly through their influence on EMS adaptation (Lages et al, 2013). Calantonne et al. (2006) and Aaby and Slater (1989), relate directly EMS to EP and indirectly company characteristics to EP through EMS. This latter depends on size, age, international experience, resources and barriers. In our study, we argue, like Rundh (2007), that size, age and international experience, resources and barriers influence EMS, which in turn determines EP (Cavusgil and Zou, 1994). As for size, it is assumed under EMS to have a direct effect on EP (Mavrogiannis et al, 2008).

## 2.1 FACTORS OF EMS ADAPTATION

EMS adaptation is determined by age, international experience, resources and barriers (Hoang, 1998). Given the perception of opportunities and threats of the target export market, the company mobilizes resources to develop an EMS and chooses an adaptation degree (Lages et al , 2013). What follows examines successively the effect of resources, barriers, age and international experience on EMS adaptation.

### 2.1.1 EFFECT OF RESOURCES ON EMS

Company resources are important in the development and implementation of EMS. The allocation of adequate resources to EMS reduces uncertainty and leads to better performance. Knight and Cavusgil (2004) show that success in foreign markets is largely determined by intangible resources. Similarly, Camison and Villar- Lopez (2010), believe that technological and organizational resources are crucial to the success of EMS. The effect of resources on EP is captured directly by some researchers (Alvarez, 2004; Wilkinson and Brouthers , 2006) and indirectly through export strategy, among others (Cavusgil and Zou , 1994; Navarro et al , 2010). Thus, we formulate the first hypotheses H1: Company resources act positively on EMS.

H 1-1: Technological resources positively influence EMS.

H 1-2: Organizational resources positively affect EMS.

### 2.1.2 EFFECT OF EXPORT BARRIERS ON EMS

Leonidou (2004) distinguishes between internal and external barriers. Internal barriers relate to the attitude of the manager and lack of resources and trained personnel. Ortiz and Ortiz (2010), categorize barriers into four groups; those related to resources, to knowledge, to procedures and to external barriers. Research on managers' perception of export barriers and their effect on EP reached mixed results. Madsen (1987) found that perception of barriers has a negative effect on EMS and EP while Zou and Stan (1998) found that the perception of barriers is not connected to EP. We line ourselves with Madsen (1987) and formulate the second hypothesis of our research H2 : Barriers to export negatively influence EMS adaptation.

H2 -1 : Internal barriers have a negative effect on EMS adaptation.

H2 -2 : External barriers have a negative influence on EMS adaptation.

### 2.1.3 EFFECT OF INTERNATIONAL EXPERIENCE

International experience relates to SME's experience as an actor in international trade (Cavusgil and Zou, 1994). This experience enables the company to detect differences between markets and take them into account to develop a suitable marketing strategy (Park, 2006). It allows the company to accumulate knowledge about foreign markets and to better respond to customer needs. Camison and Villar- Lopez (2010) argue that international experience influences choice of EMS. International experience facilitates understanding markets and results in a tailored EMS. Several authors such as Cavusgil and Zou (1994), Sousa and Bradley (2008) indicate that international experience positively relates to EMS adaptation. Like Camison and Villar- Lopez (2010),we formulate the following hypothesis: H3: The firm's international experience positively affects EMS.

### 2.1.4 EFFECT OF FIRM AGE ON EMS

Research that has examined the effect of firm age on EP led to mixed results. Some researchers found that older and more experience firms are more likely to develop an appropriate strategy and export successfully (Kaynak and Kuan , 1993). Seifert and Ford (1989) found a positive relationship between firm age and PE. Old but innovative firms can be dynamic and successful in exporting. However, younger firms are more open to the exterior and act dynamically and pro-actively than older firms (Zahra et al. , 2000). Contractor et al (2005) find no significant relationship between firm age and PE. Then, it is not so much firm age which directly affects its performance, but rather through its dynamism in terms of resources and distinctive competencies. Thus, we support the following hypothesis: H4: Firm age positively affects EMS.

## **2.2 FACTORS OF EP**

Several studies highlighted the central role of EMS as a factor of EP (Lages et al, 2013; Cavusgil and Zou, 1994). It is EMS which allows the firm to achieve the export objectives. We examine, in what follows, first the effect of EMS on EP and second the relationship between size, EMS and EP.

### **2.2.1 EFFECT OF EMS ON EP**

Marketing research has long focused on the standardization - adaptation debate of MS in foreign markets. Standardization and adaptation are the two poles of the same continuum (Jain, 1989). Tantong et al. (2010) argue that adaptation of marketing mix positively affects EP. Mavrogiannis et al. (2008) found that adaptation of EMS positively affects EP of Greek SMEs. Similarly, Zou and Cavusgil (2002) found a positive relationship between full adaptation of MS and PE. Navarro et al. (2010) use an aggregate measure of the of EMS adaptation degree to evaluate its effect on PE of Spanish companies. Like this line of this research, we put forward the following hypothesis H5 : EMS adaptation positively affects EP.

H5- 1: EMS adaptation positively affects EP growth.

H5- 2: EMS adaptation positively determines EP competitiveness

### **2.2.2 EFFECT OF SIZE ON EMS AND EP**

The relationship between size and EP has been widely studied by international marketing researchers. However, researchers do not agree on the nature of this relationship. Some found a positive correlation between size and EP (Aaby and Slater, 1989), others found a negative relationship (Mavrogiannis et al, 2008) while others found no significant relationship between them(Contractor et al. 2005). Despite these conflicting empirical findings, Hoang (1998) note that most of the research points to a positive relationship between size, measured by the number of employees, and EP. Aaby and Slater (1989), consider the direct and indirect effect of size on EP, through EMS, whereas proponents of the resources approach support the presence of a direct positive relationship between company size and performance (Barney, 1991). We propose, like Aaby and Slater (1989), that SMEs size positively influences EMS (H6- 1) and PE (H6 -2).

H6- 1: Firm size positively affects EMS

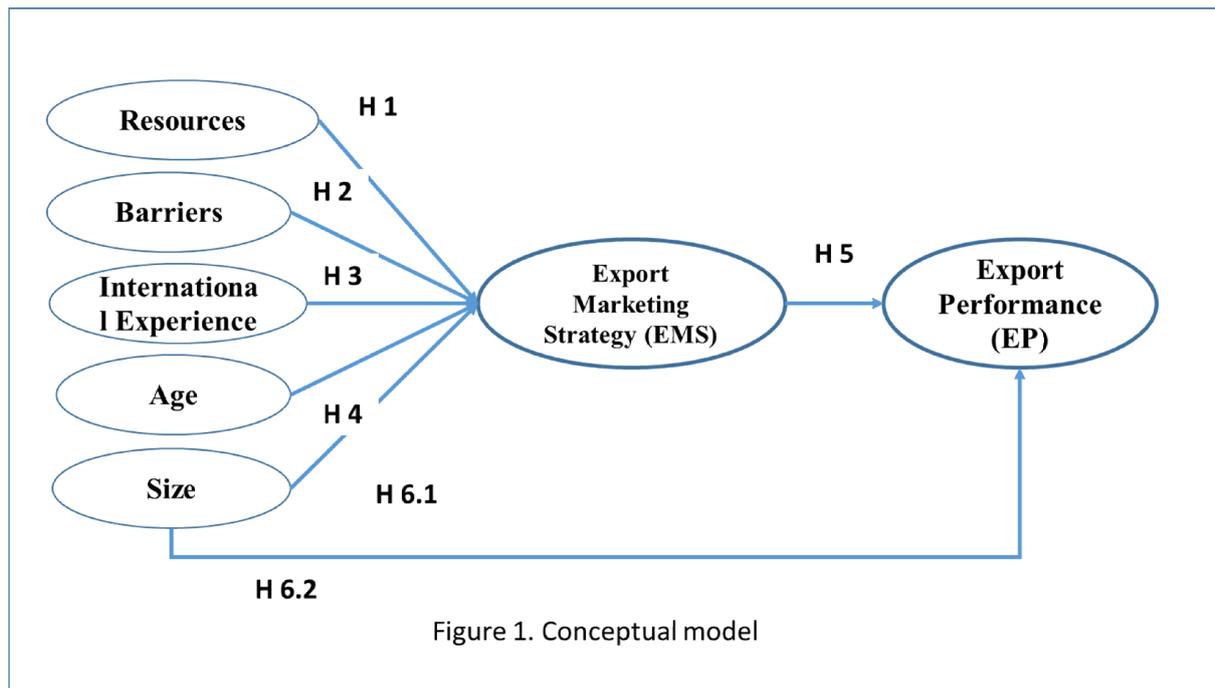
H6 -2: Firm size positively affects the EP.

H 6-2-1: Firm size positively affects EP growth.

H 6-2-2: Firm size positively influences EP competitiveness.

## **2.3 THE MODEL**

The aim of the study is to identify factors behind choosing EMS and factors affecting EP while validating the structure of our conceptual model. This model (Figure 1) includes, first, age and international business experience, resources and barriersto EMS, and second, firm size and EMS with EP and examines the hypotheses formulated above.



### 3 DATA COLLECTION AND MEASUREMENT OF VARIABLES

We will specify in what follows the data collection method and measurement scales of the variables in our model.

#### 3.1 DATA COLLECTION

The data needed for the analysis were being collected through a survey questionnaire, with managers of a sample of 206 Tunisian partially-exporting SMEs. The questionnaire was developed from the literature review. It was then revised and corrected after being tested with two teachers and eight export experts of Tunisian SMEs to ensure clarity and consistency.

#### 3.2 MEASUREMENT OF VARIABLES

Most of the variables integrated into our model are defined as latent variables measured by multiple-item scales based on managers' perception of (Katsikeas et al, 1996). The latent variables are EP resources, barriers and EMS adaptation degree. The retained EP measurement scale is taken from previous work. It consists of sales growth rates (Sousa and Bradley, 2008) and export profits (Mavrogiannis et al, 2008), manager's satisfaction with export sales growth (Katsikeas et al, 2000), exports profitability, export sales (Katsikeas et al, 2000), firm competitiveness and export objectives achievement (Lages et al, 2008). This scale uses a of 1 to 5 scale (Camison and Villar- Lopez, 2010). EP is measured by both competitiveness and export activity growth. EMS adaptation is measured by Mayrogianis et al. (2008) three-item scale, that was used by Navarro et al. (2010). We included into it importance of allocated exportation budget compared to that of competitors (Lages et al., 2008). EMS adaptation degree is measured using a five-point scale ranging from 1 "no adaptation" to 5 "very high adaptation". The importance of allocated exportation budget compared to that of competitors was measured by a scale ranging from 1 "very small" 5 "very important". Firm size was measured by the number of full-time employees (Mavrogiannis et al, 2008) while the variable firm age was assessed by the number of years from the foundation of the. As for international experience, it was measured by the number of years from the start of the export activity (Contractor et al, 2005). The scale of the variable resources was developed based on the work of Katsikeas et al, (2002), as well as that of Camison and Villar-Lopez (2010). Managers were asked to rate on a five-point scale the level of resources committed for export compared to key competitors. The scale of barriers to export was developed from the scales of Leonidou (2004), Rutihenda (2008), and Tesfon and Lutz (2006). A 5-point likert-type scale ranging from 1: "very high negative effect" to 5 "very small negative effect" was used.

## 4 DATA PROCESSING AND INTERPRETATION OF RESULTS

We will specify in what follows the methods of data processing and interpretation of the obtained results.

### 4.1 DATA PROCESSING

The aim of our research is to identify factors that explain marketing strategy adaptation and EP. To this end, data analysis consisted of an exploratory and confirmatory factor analysis and an estimation of the global model using structural equation modelling.

#### 4.1.1 THE EXPLORATORY FACTOR ANALYSIS

The number of factors to be extracted is shown by the KMO index. Clustering of variables around common factors are the measurement scales of the latent variables associated with the different factors. Reliability of measurement instruments is checked using alpha Cronbach's alpha which measures consistency of the set of positively correlated variables.

#### 4.1.2 THE CONFIRMATORY FACTOR ANALYSIS

Confirmatory factor analysis (CFA) is used to validate measurement instruments of the latent variables and the theory on which they are based. The LISREL 8.80 software provides a set of statistical tests to decide on the quality of a model and to validate hypotheses (Ralph, 1999). The most commonly used indices to validate a theoretical model are Chi-square/dl, RMSEA, GFI, AGFI, NNFI and CMA.

#### 4.1.3 ESTIMATION OF THE STRUCTURAL MODEL

The model estimation is conducted through the use of structural equation models.

##### a- Resources measurement model

To identify the "Firm Resources" variable, we took into account factors related to the organization, as well as those characterizing technology. Jöreskog's Rho allows for assessing the good reliability of the measurement scale of resources. Fit indices, presented in Appendix 1, show acceptable values and allow us to validate the measurement model of the variable "Resources".

##### b- Barriers measurement model

The variable "Barriers" is measured by seven items and is structured around two dimensions: "internal barriers" and "external barriers". Fit indices allow us to accept the measurement model of the variable "Barriers".

##### c- EMS measurement model

EMS includes the following four items: promotion adaptation, price adaptation, original product adaptation and importance of export budget. EMS fit indices indicate a good fit between the data and the measurement model, as well as a low residuals.

##### d- EP measurement model

Data on EP are structured around two dimensions: "growth" and "competitiveness". Growth includes three items while competitiveness includes two. EP fit indices (Appendix 1) indicate a good fit between data and model. Relationships between variables are presented in the diagram representing the analytical model in Figure 2 (Appendix 3). The ability of the model to reproduce the data is evaluated using fit indices of Appendix 1. Results in the diagram confirm the structure of our model.

### 4.2 PRESENTATION OF THE RESULTS

Structural equations reflect the direct effects of independent latent variables on the dependent variables and / or between dependent variables. The obtained structural relationships are below.

(1) PERFCROI = 0.71*STRMARK + 0.11*TAILLE,						
	(0.099)		(0.049)			
	7.11		2.30			
(2) PERFCOMP = 0.73*STRMARK + 0.092*TAILLE,						
	(0.1)		(0.054)			
	6.69		1.70			
(3) STRMARK = 0.28*OBSEXTER - 0.38*OBSINTER + 0.39*AVTECH - 0.23*AVORG + 0.080*TAILLE -						
0.18*EXP + 0.086*ANNCREAT,						
	(0.15)	(0.15)	(0.1)	(0.12)	(0.061)	(0.071) (0.072)
	1.84	-2.54	3.43	-2.00	1.31	-2.56 1.20

Both equations (1) and (2) indicate that there is a significant positive relationship between EP and EMS. A high level of WMS adaptation enables SMEs to achieve high EP. As indicated in the table in Appendix 2, this result indicates that EMS adaptation has a positive effect on EP. This is consistent with several researchers (Lages, 2000; Lages, et al, 2013; Beleska - Spasova et al, 2011) who found a positive relationship between EMS adaptation and EP. Concerning the effect of firm size on EP, the result is mixed. Equation (1) indicates that firm size positively influences EP growth. This is similar to research establishing a positive relationship between size and EP (Lages and Melewar, 1999). Equation (2) indicates that the relationship between size and EP competitiveness is not significant joining findings that suggest that EP is independent of the firm size (Lages and Melewar, 1999). Moreover, it shows that firm size has a significant positive effect on EP growth, i.e. the largest Tunisian SMEs are able to obtain a strong growth in export sales and profits. Finally, equation (3) links EMS adaptation with technological and organizational resources, barriers, age, international experience, firm size. It shows, first, that technological resources positively affect EMS and, second, that international experience negatively affects EMS. The first relationship that links resources and EMS adaptation joins the assumptions of the resource-based theory and the findings of Beleska - Spasova et al. (2011), which highlighted the presence of a positive effect of technological resources on export strategy. This result supports the critical role of technological resources in the success of SMEs international operations. As to the second relationship, it reflects the rigidity induced by the large size of SMEs and expresses the larger SMEs' preference for a standardization strategy. Equation 3 also indicates a significant negative relationship between EMS and international experience. It suggests that SMEs with a wide international experience tend to adopt a low adaptation degree of their marketing strategy and to put in place strategies that have already proven to work in the past. It suggests, however, non-significant relationships between internal and external barriers, organizational benefits and firm age and EMS adaptation degree. It follows from the three previous equations shown in Appendix 2 the main results concerning the validation of our research hypotheses.

Hypothesis  $H_{1-1}$ , which assumes the presence of a positive effect of technological resources on EMS adaptation, is validated and confirming the results obtained by Mavrogianis et al, (2008) and Beleska - Spasavo et al.(2011).  $H_{1-2}$  hypothesis, which assumes that managerial resources positively affect EMS adaptation, is not validated. Hypotheses  $H_{2-1}$  and  $H_{2-2}$ , which assume that internal and external barriers have a negative effect on EMS adaptation, have not been verified since the results indicate that the relationship between these variables is not significant. Regarding  $H_3$  hypothesis on the positive effect of international experience on EMS adaptation, the results indicate that it is not accepted and indicate that international experience results in a significant negative effect on EMS adaptation. In other words, the more the company is internationally experienced, the more it will tend to standardize its EMS. As for the  $H_4$  hypothesis, which links firm age and EMS adaptation and suggests a positive relationship between age and EMS, it is not significant. Regarding  $H_{5-1}$  et  $H_{5-2}$ , which assume the positive influence of EMS adaptation on the two dimensions of EP, namely growth and competitiveness, the results indicate they are validated for growth and size and for competitiveness. Finally, for  $H_{6-1}$ ,  $H_{6-2-1}$  and  $H_{6-2-2}$  on the effect of size on EMS and EP, only  $H_{6-2-1}$  hypothesis that assumes the effect of firm size on EP growth dimension, is validated. However,  $H_{6-1}$  and  $H_{6-2-2}$  were not validated because the statistics obtained respectively on the relationship between, on the one hand, size and EP competitiveness dimension and, on the other, size and EMS adaptation are not significant.

## 5 DISCUSSION AND CONCLUSION

The aim of this work is to identify the factors that determine EMS and EP of Tunisian SMEs and validate the structural model developed from previous research. The choice of SMEs as an object of research is justified by the fact that the Tunisian industrial fabric is made up of more than 85% of SMEs. A questionnaire survey was conducted on 206 partially-exporting SMEs. As for factors of PE export, the obtained results indicate that EP is positively influenced by EMS adaptation degree. The SMEs that are able to adapt their marketing strategies to foreign markets requirements have higher performance in terms of growth and competitiveness, than those that simply export the same, without an effort to adapt.

The results indicate that technological resources, which generate a competitive advantage, are EMS adaptation and alignment factors to target market requirements and allow obtaining high EP. Thus, SMEs that have technological resources and tend to adapt their EMS are able to obtain a strong growth in export sales and profits. Adaptation of the marketing strategy is an export success factor in a context of market volatility (Prasertsakul , 2013). These results also indicate that firm size directly and positively affect the EP growth dimension. They also show that barriers, organizational benefits, age and size are perceived by managers as not having an effect on EMS. They suggest that SMEs in emerging countries that adjust their marketing strategy to the requirements of foreign customers are able to achieve better performance in terms of growth and competitiveness, as thanthat use a standardization strategy. These results are identical to the results obtained, among others, by Cavusgil and Zou (1994), Lee and Griffith (2004), Lages, Jap and Griffith (2008) and Lges et al , ( 2013). Furthermore, partially-exporting Tunisian SMEs with extensive international experience adopt a low level of EMS and reach nevertheless high performance. This result seems to be explained by the reluctance of managers to change strategies that have been proven and they trend to standardize products and consumption worldwide.

On a practical level, a high level of EMS adaptation allows SMEs to compete internationally and to achieve high sales growth. Therefore, exporting SMEs managers are encouraged to adapt their EMS to achieve the objectives they seek and be satisfied with the achievements. They are also expected to be equipped with the best technological resources to give them an edge to enhance their competitive ability against competitors.

## LIMITATIONS AND FUTURE RESEARCH

Given the complexity of export and the multiplicity of factors which could determine the choice of EMS and EP level, our study did not include these factors in the theoretical model. Therefore, we have not taken into account the effect of external factors in the environment on EMS and EP. Further research could include, for example, external factors related to the domestic market and examine their effect on EMS and EP. Moreover, the results of our study can be biased due to the fact they examined data on managers' perceptions about their satisfaction with the achievement of their export activities referring to the main export market. Moreover, our findings are not generalizable given the relatively small sample size. Non-significant relationships may result from non-linear relationships between the variables of the model and the specificities of the studied countries: level of development, small market, etc. . They could also be due to sample heterogeneity, which is not made up of companies belonging to the same sector, not exporting the same products and not operating in the same country or region.

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## APPENDICES

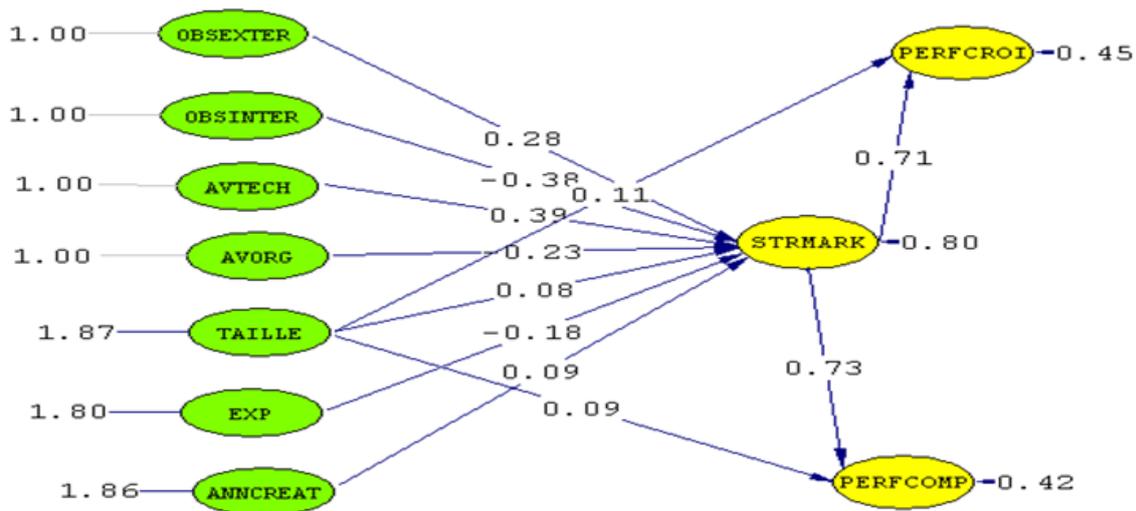
## APPENDIX 1 : FIT INDICES OF MEASUREMENT MODELS

Indices	Critical levels	Resources	Barriers	EMS	EP	Global Model
$\chi^2/df$	Inf. or = 5	1,54	4, 2	0,94	3,58	3,3
RMSEA	Inf. or = 0,05	0,047	0,036	0,0	0,0	0,05
GFI	Sup. or = 0,9	0,99	0,98	1,0	1,0	0,86
AGFI	Sup. or = 0,9	0,95	0,95	0,98	0,98	0,81
RMR	Inf. or = 0,05	0,035	0,05	0,021	0,044	0,05
NNFI	Sup. or = 0,9	0,99	0,90	1 ; 0	1,0	0,93

## APPENDIX 2 : VALIDATION OF RESEARCH HYPOTHESES

Hypotheses	Relationships	Expected Sign	Obtained Result	Observation
H <sub>1-1</sub>	Resources affect + EMS	+	+ Significant	Accepted.
H <sub>1-2</sub>	Organizational resources affect + EMS	+	Non significant	Rejected
H <sub>2-1</sub>	Internal barriers affect - EMS;	-	Non significant	Rejected
H <sub>2-2</sub>	External barriers affect - EMS;	-	Non significant	Accepted.
H <sub>3</sub>	Firm international experience affects + EMS.	+	- Significant	Rejected
H <sub>4</sub>	Firm age affect +EMS	+	Non significant	Rejected
H <sub>5-1</sub>	EMS adaptation affects + EP growth dimension.	+	+ significant	Accepted.
H <sub>5-2</sub>	EMS adaptation affects + EP competitiveness dimension.	+	+ Significant	Accepted.
H <sub>6-1</sub>	Firm size acts + on EMS	+	Non significant	Rejected
H <sub>6-2-1</sub>	Firm size acts + on EP growth dimension.	+	+ Significant	Accepted.
H <sub>6-2-2</sub>	Firm size acts + on EP competitiveness dimension.	+	Non significant	Rejected

Figure 2: The structural model



MODELE STRUCTUREL

## The Effect of Using Discovery Learning Strategy in Teaching Grammatical Rules to first year General Secondary Student on Developing Their Achievement and Metacognitive Skills

*Prof. Dr. Abdelrahman Kamel Abdelrahman Mahmoud*

Professor of curriculum and teaching methods,  
Faculty of Education, Fayoum University, Egypt

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**ABSTRACT:** The research problem is summarized in the shortage of the teaching methods used in the teaching of grammatical rules that led to a decline in the level of achievement and failure in the development of skills beyond the knowledge of students in the first grade secondary illustrated by numerous students.

**KEYWORDS:** Learning Strategy, Grammatical Rules, Student, Metacognitive Skills.

### RESEARCH PROBLEM:

The research problem is summarized in the shortage of the teaching methods used in the teaching of grammatical rules that led to a decline in the level of achievement and failure in the development of skills beyond the knowledge of students in the first grade secondary illustrated by numerous students.

Despite the demonstrated previous studies of the feasibility of these strategies in achieving some of the goals of the Arabic language, the researcher did not find the study of Arabic and one sent to the pairing of discovery learning and skills development of metacognition in grammatical rules and this is what the researcher is trying to reveal through this research.

Based on the above, current research tries to answer the question the following: (What's effective use of discovery learning strategy in the teaching of grammatical rules for first-grade students in the development of secondary attainment, and what metacognitive skills ?)

The ramifications of the previous question raise the following sub-questions:

1. What metacognition skills appropriate knowledge to secondary first-graders?
2. How can the organization of the fourth unit of the decision of grammatical rules for first grade secondary using the discovery learning strategy for the development of collection and what skills and knowledge behind?
3. What is the impact of the use of discovery learning strategy in the teaching of the fourth unit of the decision of grammatical rules for first grade secondary to the development of the metacognition skills?

### RESEARCH LIMITS:

1. A sample of secondary schools first-graders in Fayoum governorate.
2. What appropriate skills and knowledge for first grade secondary students that are determined through research.
3. The fourth unit assessed on the first secondary grade students.

#### RESEARCH OBJECTIVES:

Current research aims to stand on:

- 1 - Determine what skills and knowledge behind appropriate for first graders secondary.
- 2 - Determine the effectiveness of discovery learning strategy in the teaching of grammatical rules in the development and skills beyond the knowledge of students in the first grade secondary.

#### THE IMPORTANCE OF RESEARCH:

This research may be useful in:

- 1 - directing curriculum planners of grammatical rules to take into account the discovery learning strategy during the construction of these approaches.
- 2 - Provide a procedural model for how to use the discovery learning strategy in the field of teaching grammatical rules for first grade secondary.
- 3 - Provide one of modern strategies in the teaching of grammatical rules a discovery learning strategy in teaching grammatical rules rather than traditional methods.
- 4 - The development of appropriate metacognitive skills for secondary first-graders.

#### SEARCH SAMPLE:

The sample consists of a group of first-grade secondary students. The researcher randomly selected schools in the province of Fayoum divided into two groups; one group is considering using experimental discovery learning strategy and the other a control group taught in the traditional manner.

#### RESEARCH METHODOLOGY:

Current search will depend on:

- 1 - descriptive approach: in the theoretical framework of the research in the light of the references and previous studies and the preparation of search tools.
- 2 - Quasi-experimental approach: The strategy is the use of discovery learning to teach students of the experimental group.

#### SEARCH TOOLS:

Will be to search tools:

- pilot Tools:

- 1 - student handbook entitled: "The use of discovery learning strategy in teaching topics fourth unit is assessed on the first - grade students for the development of secondary attainment and skills beyond knowledge."
- 2 - A teacher's guide entitled "Use of discovery learning strategy in teaching topics fourth unit is assessed on the first - grade students for the development of secondary attainment and skills beyond knowledge."

- Measurement tools:

- 1 - a questionnaire what skills and knowledge behind.
- 2 - A test to determine what skills and knowledge appropriate for first grade students at secondary research sample (prepared by the researcher).

#### **RESEARCH HYPOTHESES:**

Current search will test the following hypotheses:

- 1 - There are no statistically significant differences between the duplicates Alohas and expected frequencies beyond the skills knowledge appropriate to grade students for the first year secondary.
- 2 - There is no statistically significant difference between the mean scores of students of experimental and control groups in the post application to test the skills and knowledge behind for the experimental group.
- 3 - There is no statistically significant difference between the mean scores of students of experimental and control groups in the tribal application to test the skills and knowledge behind.

Steps:

To answer the first question of a search (what metacognitive skills appropriate for first-grade secondary students?) The answer can be made according to the following steps:

- 1 - Review some of the studies and previous educational literature that dealt with the skills and knowledge behind.
- 2 - Prepare a questionnaire Ole these skills by referring to previous studies and research.
- 3 - Show the questionnaire on a group of arbitrators to determine the suitability of these skills to first-graders secondary.

To answer the second question of the search is (how can the organization of the fourth unit assessed on first-graders secondary using a strategy of discovery learning to develop skills beyond the knowledge of students in the first grade secondary?) The researcher introduced the definition of multi - strategy discovery learning and identified operational definition, and then explained how to apply this strategy in the field of grammatical rules, and finally a description of the organization of the content of the fourth unit assessed on first-graders secondary in light of this strategy through a handbook for students and a teacher's guide to learn how to use the strategy to explain the lessons of the fourth unit assessed on first-graders secondary.

To answer the third question of a search (what effect the use of discovery learning strategy in the teaching of the fourth unit assessed on the first secondary grade students to develop the skills and knowledge behind?) Can be according to the following steps:

- 1 - set up a test to measure what skills and knowledge behind and set scientifically tribal then be applied to the first grade students secondary.
- 2 - Teaching Unit IV assessed on the first secondary grade students using the discovery learning strategy.
- 3 - Application of T test.
- 4 - Processing and interpreting the results and make recommendations and proposals.

#### **RESULTS OF THE STUDY:**

Results of the application questionnaire what skills and knowledge behind.

##### **1 - Ch2 account for a questionnaire beyond the skills of knowledge:**

To calculate the Ch2 to get feedback from mentors to learn skills beyond the appropriate knowledge to first-graders and secondary were mentors responses on this way.

Table (1)

Views of the Arabic language in the guides skills beyond the appropriate knowledge to first - grade students general secondary.

No skill	Very suitable	suitable	Inappropriate	Total CA2 each skill	Relative weight	Skills arrangement based on relative weight
1	17	1	2	12,76	91,	98,
2	7	5	8	847,	65,	95,
3	8	5	7	282,	68,	93,
4	8	6	6	976,	70,	91,
5	6	8	6	4,794	66,	90,
6	7	6	7	1,325	66,	88,
7	6	5	9	1,929	61,	73,
8	16	1	3	9,85	,88	70,
9	5	7	8	4,321	61,	70,
10	7	7	6	2,408	68,	68,
11	6	6	8	2,029	60,	68,
12	6	5	9	1,929	61,	66,
13	6	8	6	4,794	66,	66,
14	16	2	2	9,82	90,	66,
15	7	6	7	1,244	66,	66,
16	9	6	5	1,226	73,	65,
17	8	6	6	976,	70,	61,
18	19	1	-	13.38	98,	61,
19	18	1	1	16,24	95,	61,
20	17	2	1	13,08	93,	60,

Based on the above table, the researcher chose skills (18 - 19 - 20 - 1 - 14 - 8) function through the value of CA 2 each skill; with the highest relative weights and meaning so that the researcher has chosen the following six skills:

- 1 - procedural behavior Skill
- 2 - declarative Skill
- 3 – conditional Skill
- 4 – Planning Skill
- 5 – regulation Skill
- 6 –testing skill

## 2 -: the results of the application of the test of metacognition skills (tribal).

To test a second hypothesis:

There is no statistically significant difference between the mean scores of students experimental and control groups in the tribal application to test the metacognitive skills. The researcher prepared a test of metacognition skills in the teaching of grammatical rules and after the application of the test tribal and monitoring results, where the application through: Calculate the arithmetic mean of the scores and the standard deviation of the test account (v) (Annex 13); to identify significant difference between the averages in pretest between the control group and the experimental group as shown in the table (22).

Value (v) and statistical significance between the mean scores of students of the control group and the experimental group in the application as a whole tribal Table (2)

Value (v) the calculated value (v) degree of tabular

Freedom of the standard deviation of the mean number (n) of statistical data application

Table ( 2 )

Statistical data Application	No of " N"	Mean Scores	Standard deviation	T - test		Calculated T-test
				0,05	0,01	
The control group	26	17,52	15,82	1,676	2,403	,1238 Not significant
The experimental group	25	17	14,77			

It is clear from the table above (2) the lack of a statistically significant difference between the experimental and control groups in total in the pre - test the skills and knowledge behind.

**3: Results of the application of T test skills of metacognition.**

The third to test the hypothesis of a search:

There is no statistically significant difference between the mean scores of students experimental and control groups in the post application to test the skills and knowledge behind for the experimental group.

The researcher prepare a skills test metacognition in the teaching of grammatical rules and after the application of the T test and monitoring results, where the application through: Calculate the arithmetic mean of the scores and the standard deviation of the test account (v); to identify significant difference between the averages in the post-test between the control group The experimental group .

The following table illustrates this. Table (3)

T. value and statistical significance between the mean scores of students of the control group and the experimental group in the post in the test as a whole

Effect size value (v) the calculated value (v) degree of tabular

Freedom of the standard deviation of the mean number (n) of statistical data

**Table (3)**

Statistical data Application	No of " N"	Mean Scores	Standard deviation	Free degree	T - test		Calculated T-test	Effect size value (v)
					0,05	0,01		
the control group	26	48,2	5,54	49	1,676	2,403	4,166	26,
the experimental group	25	56,94	8,76					

It is clear from the above table (No. 3) there is a statistically significant difference between the experimental and control groups in total in the post-test the skills of metacognition in favor of the experimental group. ; Also clear that the size of Ale the robber where it is greater than (6), which is equal to (26),.

The following table illustrates the value of "T" between the scores of students of the control group and the experimental group in the tribal application.

Table (4)  
Skilled pilot control value "v"

Skill	the control group	the experimental group	the value of "T"
1 - procedural behavior Skill	2,72 Mean Scores	2,07 Mean Scores	77,
	2,07 Standard deviation	1,82 Standard deviation	
2 - declarative Skill	2,32 Mean Scores	2,46 Mean Scores	285,
	1,22 Standard deviation	2,17 Standard deviation	
3 – conditional Skill	2,96 Mean Scores	1,92 Mean Scores	068,
	2,92 Standard deviation	2,23 Standard deviation	
4 - Planning Skill	3,12 Mean Scores	2,69 Mean Scores	722,
	2,43 Standard deviation	1,75 Standard deviation	
5 - regulation Skill	3,2 Mean Scores	3,23 Mean Scores	581,
	1,91 Standard deviation	1,77 Standard deviation	
6 –testing skill	3,23 Mean Scores	3,38 Mean Scores	,274
	2,52 Standard deviation	2,14 Standard deviation	

And adopt from the previous table that the value of the "T" in the previous skills is significant at the 0.05 level, which indicates a lack of superiority degrees students Mahmuah the experimental control group students in the pre - test in the skills and knowledge behind.

The following table illustrates the value of "T" between the scores of students of the control group and the experimental group in the post.

Table (5)  
Skilled pilot control value "v"

Skill	the control group	the experimental group	the value of "T"
1 - procedural behavior Skill	8,72 Mean Scores	10,9 Mean Scores	2,83
	2,88 Standard deviation	2,57 Standard deviation	
<b>2 - declarative Skill</b>	8,16 Mean Scores	2,88 Mean Scores	3,35
	10,77 Standard deviation	2,57 Standard deviation	
3 – conditional Skill	7,84 Mean Scores	,2 Mean Scores8	*2,12
	9,31 Standard deviation	1,99 Standard deviation	
4 - Planning Skill	6,96 Mean Scores	2,47 Mean Scores	4,273
	9,54 Standard deviation	1,7 Standard deviation	
5 - regulation Skill	6,96 Mean Scores	2,34 Mean Scores	2,965
	8,77 Standard deviation	1,92 Standard deviation	
6 –testing skill	7,92 Mean Scores	3,42 Mean Scores	3,018
	10,77 Standard deviation	3,19 Standard deviation	

And adopt from the previous table that the value of the "T" in the previous skills function at the level of 0.05 and at 0.01, indicating the superiority of scores of the experimental students Mahmuah the control group students in the post - test in the metacognitive skills.

Find recommendations

- 1 - Find a questionnaire foot bout of metacognitive skills secondary students using a modern discovery learning strategy.
- 2 - Discovery learning strategy succeeded in teaching grammatical rules in the development of skills beyond the knowledge of students in the first grade secondary school year, which is reflected in the level of the students in the test scores.

3 - discovery learning strategy helped to recruit activities where students learn for themselves and apply what know it in new situations;; which in turn led to achieving effective learning.

#### **SEARCH SUGGESTIONS:**

1 - conduct research on the use of scientific discovery learning strategy among students in different rows, and in the top seminar stages.

2 - Conduct scientific research for the development of skills beyond the knowledge of students in different rows, and in the top seminar stages.

3 - Researchskills the researcher concluded that re useful in teaching first-graders secondary year.

4 - According to the use of discovery learning strategy in the development of the skills and knowledge behind.

5 - Focus on what skills and knowledge behind different; and development in all branches of the Arabic language.

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## PERSISTENCE OF LAND CONFLICTS BETWEEN MAASAI COMMUNITY AND NGORONGORO CONSERVATION AREA AUTHORITY (NCAA) IN NGORONGORO CONSERVATION AREA (NCA)

*Z. Aisia Lawuo<sup>1</sup>, Bonamax Mbasia<sup>1</sup>, and Stephen Mnyawi<sup>2</sup>*

<sup>1</sup>Institute of Rural Development Planning - Lake Zone Centre, P.O.Box 11957, Mwanza, Tanzania

<sup>2</sup>Institute of Rural Development Planning - Lake Zone Center P.O.BOX 11957, Mwanza, Tanzania

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**ABSTRACT:** This study aimed at examining root causes leading to persistence of land conflicts between Ngorongoro Conservation Area Authority (NCAA) and Maasai community in Ngorongoro Conservation Area. Specifically, the study examine causes for land conflicts between Ngorongoro Conservation Area Authority and Maasai community and examines efforts made by the government and other stakeholders to resolve land conflicts between Ngorongoro Conservation Area Authority and Maasai community. Both primary and secondary data were collected. Primary data were collected through interview, questionnaires and observation. Secondary data were collected from various reports. A total of 109 respondents were drawn from Oloirobi and Moklari /Misigyo villages out of 13,940 populations. The findings concluded that Maasai have little awareness on laws/by-laws on environmental conservation that led to the persistence of land conflicts between Maasai community and Ngorongoro Conservation Area Authority. Moreover, the study find that, the number of livestock increase yearly compared to the area located for pastoralists to graze their livestock as a result pastoralists graze in areas which is not allowed.

**KEYWORDS:** Land Conflict, Maasai Community, Ngorongoro Conservation Authority.

### 1 INTRODUCTION

Land resource conflict in Tanzania is mainly between pastoralists and conservators, peasants and pastoralists, Government and villagers, villagers and investors, mostly in Morogoro, Mbeya, Arusha and Mara regions (Olengurumwa, 2009). These land conflicts have caused harm to communities lives and animals, destruction of properties, insecurity, low productivity, accelerated food insecurity, generation of a landless class, increased poverty, and rapid environmental degradation (NGONET, 2008; Versteegen, 2001).

In Ngorongoro District, the land conflict is mainly between Maasai community and Ngorongoro Conservation Area Authority due to Maasai demand of land for cultivation and livestock while Ngorongoro Conservation Area (NCA) demand land for environment conservation and wildlife protection. Not only that but also Maasai community was forced to leave their local areas to areas where there is no enough water and pastures for their livestock (Michael, 2008). These is contributed by the presence land use plans at the community level and within the Ngorongoro Conservation Area which is not implemented and lead to ongoing conflicts over land use for agriculture and livestock (UNESCO, 2007). Foreign companies are permitted by the Ngorongoro Conservation Area to hunt different animals within the area as a result; the foreigners destruct the local property of the Maasai and lead to conflict between the local Maasai community and Ngorongoro Conservation Area officials (Shivji, 1993).

In response to this, various stakeholders including the Government, International Organizations, Non-Governmental Organizations and Community Based Organizations have made several efforts to combat the problem including: Preparation

of land use plan, establishment of policies on pastoralist and natural resources management. Introduction of Community Based Conservations (CBC) to ensure pastoralist's benefits from conservation and community are directly involved in conservation issues (Wright 1993; Western *et al.* 1994; Adams and Hulme 2001, Hackel 1999, Hulme and Murphree 2001; Mattee, 2007).

Despite of all these initiatives made by the government and other stakeholders like Ngorongoro Conservation Authority, land conflict is still persisting in Ngorongoro Conservation area. In view of this, the study aims at finding out the factors contributing to the persistence of land conflict between Ngorongoro Conservation Area Authority (NCAA) and Maasai community specifically, to identify and determine causes for land conflicts between Ngorongoro Conservation Area Authority and Maasai community within Ngorongoro Conservation Area, to determine land resources available within Ngorongoro Conservation Area and to examine efforts made by the government and other stakeholders to resolve land conflicts between Ngorongoro Conservation Area Authority and Maasai community within Ngorongoro Conservation Area (NCA) by using Oloirobi and Moklari/Misigyo villages as study area

## 2 METHODOLOGY

### 2.1 STUDY AREA

Ngorongoro district lies in the north of Tanzania 90 km west of Arusha, adjoining the southeastern edge of Serengeti National Park between 2°30' to 3°30'S and 34°50' to 35°55'E. Contiguous with Serengeti National Park (1,476,300 ha) and Maswa Game Reserve on the west (220,000 ha) and Loliondo Game Controlled Area (400,000 ha) on the north; it is also 15 km northwest of Lake Manyara National Park (32,500 ha). While Ngorongoro Conservation Area Authority (NCAA) is found in Ngorongoro District in Arusha Region. The Ngorongoro Conservation Area Authority was established in 1959 under the ordinance 413 given that the main objectives were to conserve and develop the Ngorongoro Conservation Area (NCA's) natural resources, to promote tourism and to promote and safeguard the interest of Maasai community within conservation area (UNESCO, 2007). About 129,000 people lives within Ngorongoro Conservation Area (2002 census). Also Ngorongoro ward is within Ngorongoro district, in Arusha region located in Northern Tanzania, which comprises of Oloirobi and Misigyo/Moklari villages. The choice of this ward has been influenced by the frequently occurrence of land conflicts between Ngorongoro Conservation Area Authority and Maasai community.

The Maasai pastoralists were estimated to be 60,000 with 300,000 cattle (UNESCO 2007) in Ngorongoro Conservation area this means the population growth is high compared to the total area, which is 8290 square kilometers that is for both pastoralists and Ngorongoro conservation Area Authority (NGONET, 2008).

### 2.2 CLIMATE AND PHYSICAL FEATURES

Ngorongoro ward has topographical variation. Weather in this area varies in the highlands, it is generally moist and misty, while temperatures in the semi-arid plains can fall as low as 2°C, and often rise to 35°C. The annual precipitation falls between November and April and varies from under 500mm on the arid plains in the west, to 1,700mm on the forested slopes in the east, increasing with altitude. Ngorongoro Crater is found in Ngorongoro ward. It is the largest unbroken caldera in the world which is neither active nor flooded, though it contains a small saline lake, Lake Makat, and the Gorigor swamp. Its floor, at an elevation of approximately 2,380m, measures 17.7 by 21 km and is 26,400 ha in area (3% of the NCA), with a steep rim rising 400-610m above the floor.

### 2.3 DATA COLLECTION

Both primary and secondary data were applied; Primary data were collected through interview, questionnaires and observation. Secondary data were obtained from various documents related to the problem of the study to supplement the information from primary data sources. These data were collected from, police office, WEO, Ngorongoro Conservation Area Authority offices, Division Office, reports and other documents.

Sampling unit were Heads of households and key informants including Village Executive Officers, Ward Executive Officer, Police officer, Ngorongoro Conservation Authority officers, Pastoralist Council and Division Officer who were selected purposeful as indicated in Table 1. A total of 109 sample size was obtained from 13940 households from Oloirobi and Misigyo/Moklari villages.

*Table 1. The distribution/composition of the sample size*

S.N	Category of Respondents	No. Of individuals
1.	Households members	100
2.	Village executive officers	2
3.	Ward executive officer	1
4.	Ngorongoro Conservation Authority representative's	3
5.	Police	1
6.	Division Officer	1
7.	Pastoralist Council	1
	<b>Total</b>	<b>109</b>

## **2.4 SAMPLING PROCEDURES**

Probability and non-probability sampling were used during this study whereby simple random selection procedure was used to ensure that each unit of the sample (household) is chosen on the basis of chance and purposively sampling procedure was used to select Village Executive Officer, Ward Executive Officer, Ngorongoro Conservation Authority officials, Police officials, Division Officer and Pastoralist Council.

## **2.5 DATA PROCESSING, ANALYSIS AND PRESENTATION**

The collected data were edited, compiled, classified and coded for data analysis. The processed data were analyzed through descriptive statistics. The processed and analyzed data were presented by using table and word statements.

## **3 RESULTS AND DISCUSSION**

### **3.1 OCCUPATION OF THE SAMPLE RESPONDENTS**

About 100% of sampled respondent in Oloirobi and Moklari villages were livestock keepers. But there were sample respondents who have other sources of income other than livestock keeping for instance 73.8% were casual labour, 19.7% small businesses; 4.9% were employed and only 1.6% of the sample respondent were tour guides as indicated in table 2. The result shows most of the respondents depend on livestock keeping rather than other income generating activities. It is concluded that most of respondent depend on livestock which lead to land conflicts because sometimes their livestock do not get enough water and land for pasture.

*Table 2: Income-generating activities done in the area*

Frequency	Percentage
Casual labour	45 73.8
Small business	12 19.7
Employee	3 4.9
Tour guide	1 1.6
<b>Total responses</b>	<b>61 100.0</b>

*Source: Field data, 2010.*

### **3.2 SOURCES OF LAND CONFLICTS BETWEEN MAASAI COMMUNITY AND NCAA.**

#### **3.2.1 AWARENESS ON LAWS/BY –LAWS ON ENVIRONMENTAL CONSERVATION**

This is one among the sources of land conflict between Maasai community and NCAA. The result shows 53% of the total sampled respondents were not aware of the laws/ by-laws on environmental conservation (Table 3). For instance some of respondents (47%) reported that

*“It is not allowed to cut trees without permission from the NCAA, dumping is not allowed, cultivation is strictly prohibited inside the NCAA, grazing of livestock inside crater and the forest without permission is not allowed”*

These results imply that environment destruction will increase and lead to persistence of conflict between Maasai community and the NCAA.

**Table 3: Awareness on Environmental Conservation**

Awareness level	Frequency	Percentage (%)
Aware	47	47.0
Not aware	53	53.0
Total	100	100.0

Source: Field data, 2010.

### 3.2.2 NUMBER OF LIVESTOCK

This is among the reason for land conflict between Maasai community and NCAA. The result on number of livestock revealed that cattle were 3995, sheep were 3955, goats were 3014 and donkeys were 488, this made a total of 11452 livestock (Table 4). These results signify that number of livestock is bigger compared to the area located to them since the livestock are not allowed to be grazed within the crater and the forest of NCA without the permission from NCAA but the pastoralists pastured their livestock within the crater and the forest that lead to increase and persistence of land conflict.

**Table 4: Number of livestock**

Livestock type	Frequency
Cattle	3995
Sheep	3955
Goats	3014
Donkey	488
<b>Total</b>	<b>11452</b>

Source: Field data, 2010.

### 3.2.3 NUMBER OF WILDLIFE

According to Wildlife census of 2008 number of wild herbivores was 18,983 (Table 5). These huge number of animals in a given area lead to high demand of natural resource base for their survival while the supply tend to decrease due to the static of the land and other natural resources necessary for the animals (Wamburwa, 1998). Number of livestock is 11,452 which is bigger compared to the area located, these livestock affect the wild herbivores in searching for water and pasture because the wild herbivore are free to move from all over the NCA even to the area located to the livestock (Table 4). This situation enhanced the persistence of land conflicts because the NCAA tells the Maasai pastoralists to graze their cattle in located areas but the Maasai wanted their livestock to be free all over the conservation.

**Table 5: Number of herbivores**

Herbivores type	Number in 2008 census
Wildbeest	8325
Zebra	5433
Gazelle	1195
Eland	49
Elephant	122
Black rhino	17
Buffalo	3686
Waterbuck	8
Hippo	53
Warthog	95
<b>Total</b>	<b>18,983</b>

Source: NCAA, 2008

**3.3 LAND AVAILABLE WITHIN THE NGORONGORO CONSERVATION AREA AUTHORITY**

**3.3.1 LAND AREA FOR GRAZING**

The results on adequacy of land for grazing of livestock indicated that 33% of the sample respondent reported that land for grazing is adequate meaning that, they do not have enough land to graze their livestock. Still results on land for pasture and water for livestock indicates 84% of respondents interviewed emphasizes that it is not adequate and 82% insisted that the water for livestock is not enough (Table 6). These imply that land conflict between Maasai community and NCAA will continue to harm lives of local community.

Additionally, results on arable land for cultivation indicates 96% of the interviewed respondents said land for cultivation is not adequate (Table 6). During the establishment of NCAA cultivation was allowed in the Conservation area later NCAA realized that the people through cultivation are competing with wildlife for crater resources where by in 1976 cultivation was banned as incompatible with conservation (UNESCO/IUCN 2007). It is concluded that scarcity of the land for grazing, for pasture and area for watering animals, Maasai pastoralists tends to shift to reserved and controlled area in order to get enough land, water and pasture for their livestock and lead to persistence of the land conflicts. These findings are in relation with what Kratli and Swift, (1998) already concluded that competition for access to range resources leads to conflict among pastoralists and between them and other livelihoods and land use systems that seek the use of the same resources.

*Table 6 Availability of resources in Ngorongoro ward*

Resources	Adequate (%)	Not adequate (%)	Not sure (%)	Total (%)
Land for grazing	33	66	1	100
Land for cultivation	4	96	0	100
Land for pasture	11	84	5	100
Water for livestock	18	82	0	100

Source: Field data, 2010.

**3.4 LAND CONFLICTS RESOLUTION**

**3.4.1 GOVERNMENT INVOLVEMENT IN CONFLICT RESOLUTION**

Results on government involvement in conflict resolution indicates 30% of the respondents reported that government through NCAA is involved in land conflicts resolution through various means; For instance 14% reported that government is involved in meeting for agreement, 10% said, the government through NCAA provide social services and 6% said, NCAA weaken some conservation laws such as to allow the pastoralist to graze their livestock within the crater and the Northern highland forest during the dry season (Table 7). However 70% of the respondent insisted that the government did not involved in resolving land conflicts between NCAA and the Maasai community (Table 7). This signify that Government to some areas have participated in resolving land conflict but to some areas not. These lead to persistence of conflicts between Maasai Community and NCAA.

*Table 7: Involvement of NCAA in land conflict resolution*

	Frequency	Percentage (%)
Meeting for agreements	14	14
Means for provision of social services	10	10
Weakening some conservation laws	6	6
Not involved	70	70
<b>Total</b>	<b>100</b>	<b>100</b>

Source: Field data, 2010.

In respect to Government involvement in solving land conflict between Maasai Community and NCAA, 65% of the respondent emphasized that the government through NCAA did not succeed in resolving land conflicts (Table 8).This still

signify that there is a persistence of land conflict caused by some of Government leaders who are not responsible in resolving these conflicts. These findings are supported by what Mwamfupe and Mg'ong'o, 1998 concluded. They concluded that, persistence of land conflict in many villages of Kilosa District is an indication of the weaknesses in the reconciliatory bodies. The negligence in settling lands use plan has led to the persistent of conflicts for long time without any solution. These include undermining of local tenure arrangement, land misuse and misuse of leadership position to grab land (Kapinga, 1995).

**Table 8: Perception of community on success of NCAA in land conflict resolution**

	Frequency	Percentage
Effective	35	35
Not effective	65	65
<b>Total</b>	<b>100</b>	<b>100</b>

Source: Field data, 2010.

### 3.4.2 STAKEHOLDERS' INVOLVEMENT IN LAND CONFLICT RESOLUTION

Similarly, 23% of the sample respondent explained that there were other stakeholders involved in conflicts resolution, for example Ereto-Ngorongoro Pastoralist Project was the bilateral project between Denmark and Tanzania government. It was reported that this project provides various services to Maasai community like animal medicines, education to pastoralist on better method of livestock keeping and construction of animal deep (Table 9). This project phased out in 2008 however it has reduced land conflict though conflicts still persist.

**Table 9: Involvement NGOs in land conflict resolution**

	Respondents	Percent (%)
Means for provision of social services	23	23
Not involved	77	77
<b>Total</b>	<b>100</b>	<b>100</b>

Source: Field data, 2010.

On the other hand, Most of respondents (68%) reported that the project was not effective in resolving the conflict (Table 10) though others (32%) reported that it was effective. These signify that organizations are trying to participate in resolving these conflicts but still these conflicts harm lives of local Maasai Community.

**Table 10: Perception of the community on success of NGOs in land conflict resolution**

	Respondents	Percent (%)
Effective	32	32
Not effective	68	68
<b>Total</b>	<b>100</b>	<b>100</b>

Source: Field data, 2010.

### 3.4.3 RESETTLEMENT STRATEGIES IN PLACE

The resettlement strategy was done by NCAA in collaboration with other stakeholders in order to diminish land conflict by reducing the number of people with their livestock. These was planned to be done however according to Tourism Officer of NCAA he reported that about 100 households showed their willingness to shift to Oldonyo Sambu village in Sale division which is still a small numbers as compared to NCAA expectation. These situations in one way or another still lead to land conflict persistence between Local Maasai Community and NCAA.

### 3.4.4 RE-STOCKING POLICY EXISTING IN NGORONGORO CONSERVATION AREA AUTHORITY

The restocking policy aims at improving the livelihood of Community as well to enhance the livestock keepers to benefit from their livestock (Michael, 2008).The government of Tanzania through the NCAA with other stakeholders such as Ereto

Project have restock the destitute Maasai families by providing them with livestock including cattle and goats. The Ereto project restocks over 3400 destitute families in the whole NCA. These have helped to reduce land conflicts as well as to improve the livelihood of the community. Moreover this project supported some private veterinary services that provided pastoralists with modern and accessible options for treating livestock diseases.

## **4 CONCLUSION AND RECOMMENDATION**

### **4.1 CONCLUSION**

It is concluded that the persistence of land conflicts between NCAA and Maasai community is contributed by many reasons including inefficiency of NCAA to make follow up of its rules and regulation on environmental conservation; Little awareness of the community on the environmental conservation which is influenced by low level of education of the community; for instance 61% of the sample respondent do not have primary school education; Poverty continues to increase as the number of Maasai pastoralists increases while the land resource are declining; The increase in number of livestock is very high compared to the area which was located for pastoralists to graze their livestock as a result still people are grazing their livestock within the crater and Ngorongoro Conservation Area forest which affect wild herbivores in terms of water and pasture.

### **4.2 RECOMMENDATIONS**

With regards to findings and conclusion the researchers gives the following recommendations

- The Ngorongoro Conservation Area Authority (NCAA) should provide the better livestock keeping methods to the pastoralists such as good veterinary services to the livestock and to introduce sedentarization policy to the pastoralists in order to reduce the free movements of livestock all over the Ngorongoro Conservation Area to reduce competition over resource between livestock and wildlife.
- The pastoralists should be provided with the education in order to improve awareness on various matters like environmental conservation.
- Ngorongoro Conservation Area Authority (NCAA) should be strong in implementation of its rules and regulation, for example the government was banned cultivation but the NCAA is not strictly to make sure that cultivation is prohibited.
- The government together with Ngorongoro Conservation Area Authority (NCAA) should participate with the community from the first stage to the last stage in conflict resolution rather than just giving information, this will enable the local people to participate in decision making and get better solution.
- The Ngorongoro Conservation Area Authority should educate the Maasai from the primary school to the University in order to reduce the dependence on livestock only.
- The Ngorongoro Conservation Area Authority should provide employment to the Maasai residents in various hotels, Campsites, lodges, Tented Camps, and shops in order to reduce the dependence on livestock keeping only.

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## ENVIRONMENTAL IMPACT OF INDISCRIMINATE WASTE DISPOSAL ON RIVER CHANNEL IN PART OF AKOKO-REGION, ONDO STATE, NIGERIA

*Abiodun Daniel Olabode<sup>1</sup> and Akinola Lawrence<sup>2</sup>*

<sup>1</sup>Department of Geography and Planning Science,  
P.M.B. 001, Adekunle Ajasin University, Akungba-Akoko,  
Ondo State, Nigeria

<sup>2</sup>Department of Geology, Adekunle Ajasin University, Akungba-Akoko, Ondo State, Nigeria

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**ABSTRACT:** The study investigates environmental impact of indiscriminate waste disposal on river channel in part of Akoko-Region, Ondo State, Nigeria. The study further identified; method of waste disposal within the study area, influence of waste disposal method on open space and streams, reaction of water to waste disposal method, environmental problems associated with waste deposited on river channel. Primary data for the study were generated through questionnaire administration and water sample analysis. Sixty questionnaires were systematically distributed in each of the selected sampled locations that included Ise, Akunu, Ikakumo, Ugbe and Ikare settlements based on interval of fourth house from another house. Twenty-two water samples were randomly collected from the selected sampled settlement in order to identify their physical properties using in-situ method. Simple percentages were employed for data analysis while tables and figures presented findings of study. It was observed that wastes are being flushed into streams and thereby affects the odor, taste and coloration of water quality. Flooding activities identified in this area is majorly caused by indiscriminate waste disposal that blocks water drainages. The study therefore recommends provision of waste management strategy that will ensure neatness of environment and avoid pollution of water with effective refuse collection and disposal system within the study area and the related environments.

**KEYWORDS:** Waste, Water, Management, Environment, River.

### 1 INTRODUCTION

One of the prominent components of man's environment is river that flows gently within its natural course. River serves as the source of water that man drinks. Other purposes such as agricultural and domestic purposes are also serving by water from river. River provides both defense and transportation means for human beings. Yet when the volume of water in a river smells due to disposal of indecent elements, such as wastes, it then starts to pose a threat to residents around its course.

Waste could be an unofficial measure of prosperity; it can also be a major problem on man especially where it is not well managed. Reference [1] observed that unregulated growth of urban areas and inadequate infrastructural facilities for collection, transporting, treating and disposal of waste have all contributed to increase in pollution. The heterogeneous mixture of plastics, cloths, metals and organic solution which are inevitable products of production and consumption are on increase as a result of urbanization that give room for indiscriminate discharge of solid and sewage waste into river channels thereby causing serious flooding which is a treat to life in general.

The present situation in Akoko North/East Local Government Area and in several parts of Nigeria portrays the above described situation. This study investigates the problem with a view to providing sustainable solution to the phenomenon in this fast growing part of Ondo State, Nigeria. Hence, the need for adequate and efficient waste disposal system in the study

area cannot be over emphasized. Adequate and efficient waste disposal system is required for good health and neat environment.

The effects of Waste Disposal and Management in Akoko North/East Local Government has attracted the attention of various researchers in References [2] and [3]; whose studies were limited to waste management and effects of waste on underground water, on health status and visual intrusion. Reference [4] has expressed concern on the volume and inadequate management of waste in the developing countries, the organization further reports that there is existing correlation between the quality of environment and health status of communities.

Waste disposed or flushed into the drainages and river courses in Akoko North East Local Government engender major environmental problem, particularly, in Ikare town, being the major commercial centre of the entire study area. The bulk of waste generated in Ikare are dumped into river courses which has led to a number of waste accumulation along the river courses and drainages resulting to water pollution, drainage blockage, infrastructural degradation, land pollution, flooding, erosion, as well as spread of diseases like cholera, diarrhea, typhoid fever which are water borne.

Attempts have been made by government to address the issue of waste collection and disposal within the study area. Such effort involves creation of Local Government Waste Management Board by State Government and recently Sanitation Department in the Local Government and Local Government Environmental Protection Agency [LGEPA], where Environmental Health Officer known as 'Wole-Wole' were directly involved in the past to supervise waste management of this area.

However, empirical observation reveals that at the initial commencement by the waste management board, their services were effective due to newness of its equipments especially with the assistance of the Niger Delta Development Commission [NNDC] in the supply of Dino trucks as well as the staff commitment to prompt maintenances of the waste equipments.

Things however started changing and take a new turn sooner than later as investigations reveals that this state of inefficiency as a result of insufficient Dino bin, poor maintenance of equipment, inadequate funding, greed, indiscipline, illiteracy and unconcern attitudes, from member of the public and official bodies that lead to inefficiency of effective waste management. This study therefore designed to holistically investigate effects of waste disposal along river channels in Akoko North/East with a view to provide sustainable solution to the defaced aesthetic configuration of the environment and drainage blockage in the study area. Generally, the study identifies the types of waste deposited along river courses, examines the effect of indiscriminate solid waste deposited on the river courses and underground water, and determines the impact on aesthetic value and human health and sustainable solution to the problem of improper disposal of wastes.

## 2 STUDY AREA

The study area is situated in the North senatorial district of Ondo State, Nigeria. This area is located on latitude  $5^{\circ} 30'E$  and  $6^{\circ} 05'E$  while on Longitude  $7^{\circ} 17'N$  and  $7^{\circ} 45'N$  (see figure 1). The study area shares common boundary with Akoko North/West in the Northern part, Akoko South/East in the Eastern part, Akoko South/West in the Southern part and with Ekiti State in the West.

This area observes dry season between October and March while the wet season between April and September. The terrain is an undulating valley surrounded by ridge hills and mountains especially in the south/Western parts while the terrain is fairly flat with scatter rock in the North/Eastern part of the local government covering the following towns Iboropa, Ise, Auga, Akunu and Ikakumo area.

As observed by References [5] and [6], Ikare metropolis is underlined by Precambrian basement complex rock of South/Western Nigeria. The lithological rock types include Grey gneiss, Granite gneiss, Charnockite, Granite, Quartzite and Migmatite gneiss. These rocks form residual isolated hills and continuous ridges around Ikare area.

The vegetation fall within two major type, the Sub-Tropical forest zone and the Guinea savanna zone. The forest zone is found within the South Western part of the study area, particularly in Ikare; this is characterized with tall tree and thick forest. The vegetation species include parasite, cumber and reepens with tall tree like walnut, iroko, obese, maogany and oil palm among others.

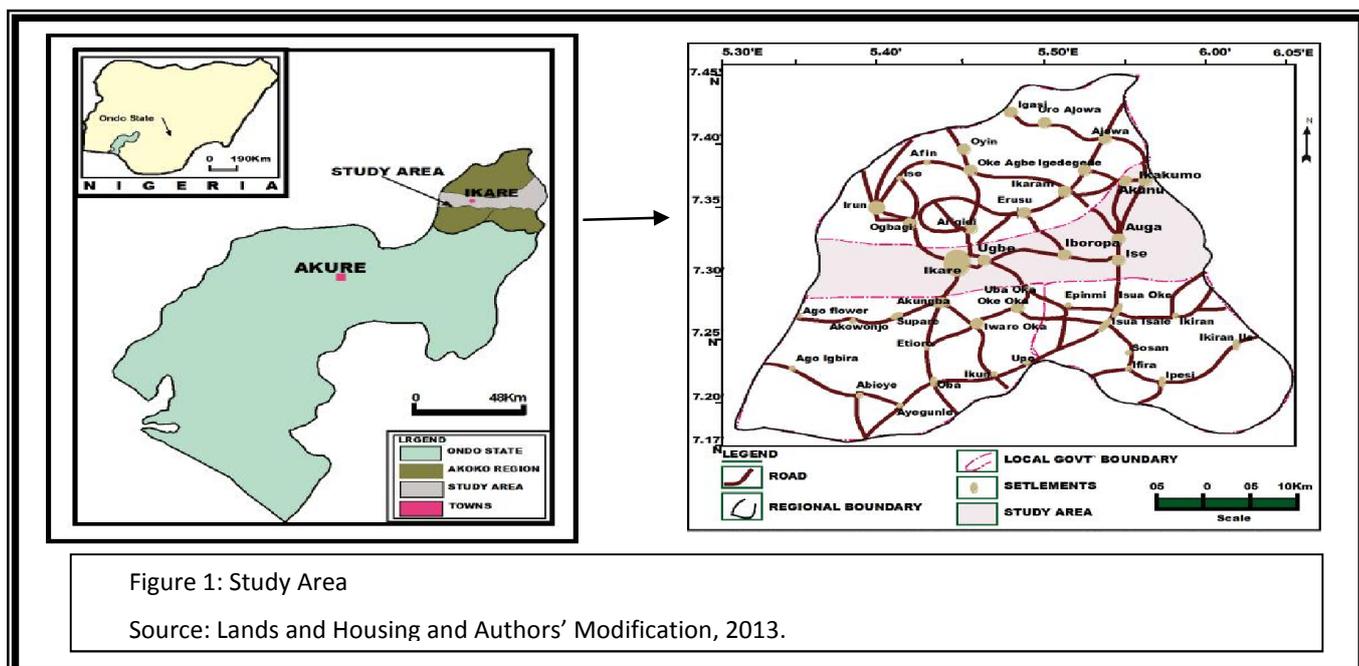
The Guinea savanna zone lies in the North Eastern part of the study area around Iboropa, Ise, Auga, Akunu and Ikakumo settlements. The vegetation is characterized with elephant grass, capet grass, cumber, parasites with mixture of tall trees scattered in the region and there are Iroko, Obeche, Maogany, Buter tree, Oil palm, Date palm among others, besides there are very many xerophitic plants.

The soil of this area is lateritic. They are grayish/reddish in color, generally sticky, impervious to water and of mediocre fertility. These soil are of little use for Agriculture thus responsible for the low in Agriculture product of the area which is limited to a root crop and cash crop e.g. Cassava, Yam, Colanut and Cocoyam.

The population of the study area according to Reference [7] is 179,092, being the 9th most populated Local Government in Ondo State. The substantial portion of the land is used for agriculture activities; places like Iborapa, Auga, Ise, Akunu and Ikakumo has about 98% of their population engaged in farming which is the sources of their living, cash and food crop are there major farm product except Ikare where there major activities is trading which eventually increase the waste deposit in the area.

Other activities involve in buying and selling and this comprises wholesale, retail sales, financial institutions, hotels and restaurants. Most of these commercial activities are been performed in the market places like Oja-Oba, Obada, Osele, Owode, Jubile, Okore, Oja-Oba Iboropa, Oja-Oba Auga, Ugbe market where solid waste predominantly generated and disposed indiscriminately into drainages.

Though every settlement has servicing road network but they are usually of low grade without adequate drainage channels. The existing channels are not maintained, being filled-up with assorted refuse that rendered it useless; especially, most bridges that link Ugbe-Iborapa, Ugbe-Epinmin, Iyame road (road from Idimango to Ese) and those at river Dada, Jubilee-Ugbe and Ikare, Ese-Jubilee, Osele Market - Olukare palace. All these observed bridges have been affected by the indiscriminate deposit of waste into the drainages.



definitions and conceptions of environment is closely linked to the facts that the study of environment is multi-disciplinary, thus each discipline tended to develop and adopt definitions in line with its interest.

Reference [9] stated that the multiplicity of the usage and concept of the term environment have resulted in a variety of adjectival forms environment which include social, moral, physical home, psychological, behavioral, geological, and geographical environment. Reference [10], for instance, defined environment as all the external and non personal conditions and influence that affect the welfare a people in a giving area. Reference [11] on the other hand defined environment as the sum total of all conditions that surround man at any point on the earth's surface. While the federal Environmental Protection Agency (Reference [12]) stated that the environment include water, air, land plant, animal human being, living there in, and the interrelationship that exists among them.

From the above definitions, environments can be view according to Reference [13] as a determinant of the characteristic futures of growth, development and sustainability of both the components element of the environment and

the environments itself. Though, evidences suggested that the prevailing global environmental degradation poses serious threat to sustenance of carrying capacity of the ecosystem. Hence, Reference [14] opined that environmental sustainability have taken priority position in housing, infrastructure provision, planning, land use and urban development among others.

Generally, Refence [15] observed that environmental problems are mostly due to developmental process and are of local, regional and global effect. These effects are viewed as consequences of human activities are most often harmful on humans being, livelihoods, animal and plant lives presently or transferred to posterity.

Man's quest for survival deteriorates the environment as we commit ourselves to a particular set of problem; more rapid depletion of domestic and greater pressure are exerted on the environment which can lead to irreversible change in life sustainability. Thus unethical waste disposal on river channels according to Owotorose (2007) must be discouraged to ensure good human health and safety in our entire environment.

### 3 MATERIALS AND METHODS

Data used for this study were sourced through questionnaire administration and water sampling. This involved the distribution of 60 questionnaires in each of the selected sample locations. The sample locations involved rural (Ise, Akunu and Ikakumo) and urban (Ugbe and Ikare) areas where human population concentrates. Systematic sampling technique was employed to select houses based on interval of fourth house in each location. Direct observation of water samples collected with in-situ test of water parameter in order to identify water physical properties. In all, 120 questionnaires were administered in the course of the study. Water samples were collected from 6 boreholes, 6 wells and 10 streams (surface water) using one (1) liter Teflon bottle container. This makes it a total of 22 water samples that represents random selection of water sources within the studied settlements. Also, depth of water level on each wells were taken with the aid of meter tape with a bulb attached to its end to allow easy immersion.

### 4 DISCUSSION OF RESULTS

#### 4.1 METHODS OF WASTE DISPOSAL IN AKOKO NORTH/EAST

The method of waste disposal employed by the people in the study area is indicated in table 1. The study identified open dump with 31.7 percent forming the highest way by which people in this area dispose their wastes. Whereas, wastes subject to burning as the second common way of waste disposal is of 25 percent. Wastes dump at stream or river channels is of 20 percent. This finding presents total of 76.7 percent refuse in the study area is responsible for overland and stream water pollution; although, the effect of the pollution is based on mode of waste evacuation, as this explains that delay in waste evacuation mostly result into terrible pollution effect in this area.

*Table 1. Method of Waste Disposal*

Disposal Method	Frequency	Percentage
Open dump	19	31.7
By burning	15	25
Dino bin	5	8.3
Dug pit	9	15
Stream/River channels	12	20
Total	60	100

*Source: Field Survey, 2013*

As observed in table 2, waste evacuation is not regularly done because it takes more than a period of one month to evacuate waste deposited in Dino bin by waste management board. This automatically leads to overflow of waste in Dino-bin that results into spreading of waste along major roads in most cases. This study confirms that refuse were not regularly collected and resulted into environmental pollution especially in urban area.

Table 2. Waste Evacuation

Period of Evacuation	Frequency	Percentage
Promptly	5	8.3
Weekly	16	26.7
Monthly	18	30
Above a month	21	35
Total	60	100

Source: Field Survey, 2013

#### 4.2 INFLUENCE OF WASTE DISPOSAL METHOD ON THE STUDY AREA

Table 3 revealed rate of waste deposition within the selected study areas. The study identified majority of people in rural area with open dump method while those in urban area prefer dumping their refuse on drainage channel as soon as it rained. This arbitrary refuse dumping usually lead to drainage blockage and worst still polluting water in rivers.

Table 3. Waste disposal methods in urban and rural area

S/N	Method of Disposal	Rural		Urban	
		Frequency	%	Frequency	%
1	Open dump	21	35	19	31.7
2	Burning	15	25	14	23.3
3	Dino bin	6	10	2	3.3
4	Dug pit	4	6.7	2	3.3
5	Stream/river	14	23.3	23	38.3
Total		60	100	60	100

Source: Authors' Field Survey 2013

For instance, the waste dumped on river Atikua, Odo, Dada and Aringa has contributed to ground water contamination that serves bore-hole and well water in the area which resulted into water coloration, especially, in urban areas. Rural area has appreciable water condition with limited or no pollution. This result shows that waste deposited on drainages should be cautioned in order to preserve adequate water condition in the study area.

#### 4.3 WASTE DISPOSAL METHOD AND WATER QUALITY IN AKOKO

Table 4 present the locations where water samples were collected and the results of the water test carried out on Wells, Boreholes and Streams within the study area. The study confirmed more water in rural area to be tasteless and colorless due to reduced activities of refuse disposal at drainage locations. Although, the result derived from borehole water shows that more of this water source are effected with odour.

It is also established that water pollution is one of the major problems commonly attributed to most of the study locations within the urban areas. This is so based on the observed effect of color, taste and odor that characterized water sources in this area. It shows that waters in rural areas such as Iboroba and Akunu have a more quality characteristics based on its physical description when considered the reduced effect of odor and color in the area. The exception of well-water salinity in Akunu is attributed to the location of the water and other external influences such as low impact of environmental degradation due to low population effect.

In addition, the study identified that depths of the sampled waters measured in meters have considerable influence on the quality of water in the study locations. For instance, within the four locations comprising of rural and urban areas, where the total of twenty-two results of physical water tests extracted shows that the deeper the water the lower the taste, color, and odor recorded; especially, the color and odor characteristics. Though, the taste perceived is not influenced in many cases even in a deeper water points. The reason for this may not be far-fetched since most of the stream waters usually serves on motion and "taste characteristics" are not easily detected. Although, contrary is for waters that are under the ground. The study shows that the influence of continuous waste deposit in this area has much influence on the water qualities in many of

the deep-bored water in the study area. This is so, because accumulations of waste deposit usually concentrate at lower grounds.

**Table 4. Water Sample and Result of Water Test in the Study Area ( In-Situ Test)**

	Sample Location	Source of Water	No of Source	Sampled Water	Depth/ Meter	Taste	Color	Odor
URBAN AREA	Ikare	Well	1	1	16	Taste	Colorless	Odor
		Borehole	1	1	48	Taste	Colorless	Odor
		Borehole	2	1	52	Taste	Colorless	Odorless
		Stream	1	1	06	Taste	Greenish	Odor
		Stream	2	1	2.0	Taste	Brownish	Odor
		Stream	3	1	1.6	Taste	Darkish Brown	Odor
	Ugbe	Well	1	1	14	Tasteless	Colorless	Odor
		Well	2	1	9.4	Tasteless	Colorless	Odorless
		Borehole	1	1	100	Tasteless	Colorless	Odorless
		Borehole	2	1	3.5	Taste	Colorless	Odorless
Stream		1	1	1.02	Taste	Brownish	Odor	
	Stream	2	1	0.8	Taste	Brownish Dark	Odor	
RURAL AREA	Iboropa	Well	1	1	12	Taste	Colorless	Odorless
		Well	2	1	15	Taste	Colorless	Odorless
		Borehole	1	1	42	Taste	Colorless	Odorless
		Borehole	2	1	46.2	Taste	Colorless	Odorless
		Stream	1	1	1.92	Tasteless	Colorless	Odorless
	Akunu	Well	1	1	14.50	Salty	Colorless	Odorless
		Well	2	1	10	Tasteless	Colorless	Odorless
		Borehole	1	1	54	Tasteless	Colorless	Odorless
		Borehole	2	1	46	Tasteless	Colorless	Odorless
		Stream	1	1	2.7	Tasteless	Colorless	Odorless

Source: Field Survey 2013

#### 4.4 WASTE DEPOSAL AND RIVER COURSE ALTERATION

Apart from the effect of waste deposition on physical characteristic of waters, the study agrees in table 5 that alteration on the course of streams does more damages and destruction to life and properties, especially in urban centers. The study gathered that "river course alteration" through indiscriminate waste deposition results into 43.3 percent and 33.3 percent of flooding activities in urban and rural areas respectively. This especially, is well pronounced in places where drainage has been badly blocked by wastes. The degenerating influence of flooding in most cases leads to overland pollution that drains into river bodies, which led to infrastructure degradation where 33.3 percent of urban and 38.3 percent rural infrastructures have been affected in the study areas (table 5).

**Table 5. Effect of Waste on River Channels**

S/N	Effect	URBAN AREA		RURAL AREA	
		Frequency	%	Frequency	%
1	Flooding	26	43.3	20	33.3
2	Erosion	9	15	10	16.7
3	Pollution	5	8.3	7	11.7
4	Infrastructure Degradation	20	33.3	23	38.3
	Total	60	100	60	100

Source: Author's Field Survey, 2013

## **5 CONCLUSIONS AND RECOMMENDATIONS**

The study revealed that wastes disposed into river/stream channels indiscriminately resulted into drainage blockage, disastrous flooding, infrastructural degradation, stream/river pollution and underground water contamination. Thus, sustainable management of waste is needed to correct this environmental anomalies that impact lives and properties. On this ground, the study suggests that there should be waste management strategy to ensure neatness of environment and avoid pollution from wastes through the provision of less strenuous and effective refuse collection and disposal system within the study area and the related environment.

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## Modeling of Total Bacterial Population on the Sliced Chicken as a Function of Period of Storage and Gamma-Irradiation Dose Given

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This paper deals with the developing the most suggested model with  $R^2 = 0.9079$  for Total bacterial count as a function of the irradiation dose and the storage period for a sliced chicken meat.

**KEYWORDS:** Irradiation, Radiation, Modeling, Cobalt-60, Radiolysis, M S Excel.

### 1 INTRODUCTION

Poultry carcasses are commonly contaminated with en-teric pathogens such as Salmonella, Campylobacter and *Listeria monocytogenes* (Jacobsreitsma et al., 1994; Murphy et al., 2004); the possibility of cross contamination of poultry carcasses post slaughter is high. Decontamination of poultry carcasses is therefore desirable. Various decontamination technologies have been proposed including the use of various chemical agents such as alkali (Rodriguez et al., 1996), physical methods such as steam treatment (James et al., 2007) and biological control with bacteriophages (Carvalho et al., 2010), but only treat-ment with water supplemented with chlorine or a chlorine-ting agent is used commercially. The effects of such decontaminating treatments are limited (Oyarzabal, 2005; Russell and Axtell, 2005).

The term "radiation chemistry" refers to the chemical reactions that occur as a result of the absorption of ionizing radiation. In the context of food irradiation, the reactants are the chemical constituents of the food and initial radiolysis products that may undergo further chemical reactions. The chemistry involved in the irradiation of foods has been the subject of numerous studies over the years and scientists have compiled a large body of data regarding the effects of ionizing radiation on different foods under various conditions of irradiation. The basic principles are well understood and provide the basis for extrapolation and generalization from data obtained in specific foods irradiated under specific conditions to draw conclusions regarding foods of a similar type irradiated under different, yet related, conditions. The types and amounts of products generated by radiation induced chemical reactions ["radiolysis products"] depend on both the chemical constituents of the food and on the specific conditions of irradiation.

The principles of radiation chemistry also govern the extent of change, if any, in both the nutrient levels and the microbial loads of irradiated foods.

Factors Affecting the Radiation Chemistry of Foods- Apart from the chemical composition of the food itself, the specific conditions of irradiation that are most important in considering the radiation chemistry of a given food include the radiation dose, the physical state of the food (e.g., solid or frozen versus liquid or non-frozen state, dried versus hydrated state), and the ambient atmosphere (e.g., air, reduced oxygen, and vacuum). The temperature at which irradiation is conducted can also be a factor, with more radiation-induced changes occurring with increasing temperature. Temperature is less important, however, than the physical state of the food. The amounts of radiolysis products generated in a particular food are directly proportional to the radiation dose. Therefore, one can extrapolate from data obtained at high radiation doses to draw conclusions regarding the effects at lower doses.

The radiation chemistry of food is strongly influenced by the physical state of the food. If all other conditions, including dose and ambient atmosphere, are the same, the extent of chemical change that occurs in a particular food in the frozen state is less than the change that occurs in the non-frozen state. This is because of the reduced mobility, in the frozen state, of the initial radiolysis products, which will tend to recombine rather than diffuse and react with other food components. Likewise, and for similar reasons, if all other conditions are the same, the extent of chemical change that occurs in the dehydrated state is less than the change that occurs in the fully hydrated state.

The formation of radiolysis products in a given food also is affected by the ambient atmosphere. Irradiation in an atmosphere of high oxygen content generally produces both a greater variety, and greater amounts, of radiolysis products in the food than would be produced in an atmosphere of lower oxygen content. This is because irradiation initiates certain oxidation reactions that occur with greater frequency in foods with high fat content.

With few exceptions, the radiolysis products generated in a particular food are the same or very similar to the products formed in other types of food processing or under common storage conditions. These radiolysis products are also typically formed in very small amounts. Radiation-induced chemical changes, if sufficiently large, however, may cause changes in the organoleptic properties of the food. Because food processors want to avoid undesirable effects on taste, odor, color, or texture, there is an incentive to minimize the extent of these chemical changes in food. Thus, the doses used to achieve a given technical effect (e.g., inhibition of sprouting, reduction in microorganisms) must be selected carefully to both achieve the intended effect and minimize undesirable chemical changes.

Typically, the dose or dose range selected will be the lowest dose practical in achieving the desired effect. Irradiation also is often conducted under reduced oxygen levels or on food held at low temperature or in the frozen state.

In general, during inactivation of microorganisms on surfaces, the rate of inactivation is inversely proportional to the initial cell concentration (Shintani, 2000). Food irradiation is being considered an important tool, in ensuring safety and extending shelf-life of fresh meat and poultry (Yoon, 2003). Thus irradiation can eliminate food-borne pathogenic microorganisms in meat. Furthermore, the use of gamma irradiation as a safety technological treatment in food preservation has now become legally accepted in many countries of the world (Abdel-Daium, 2007).

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the total bacterial count as a function of the irradiation dose and the storage period of irradiated sliced chicken meat.

## **2 MATERIALS AND METHODS**

<sup>26</sup>Sliced chicken were purchased from local market (Benha, Qalibia governorate, Egypt). All samples were transported to the laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts for counts of total bacteria, psychrophilic bacteria, spore forming bacteria, total molds and yeasts. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

### **2.1 Gamma irradiation treatments<sup>26</sup>**

Four bags from each of sliced chicken were gamma irradiated at 0, 2, 4, and 6 kGy doses using cobalt-60 gamma chamber (1.367 kGy/h) in Cyclotron Project, Nuclear Research Center Atomic Energy Authority, Inshas, Cairo, Egypt. After irradiation, all samples were stored at 4±1°C.

### **2.2 Microbial analysis<sup>26</sup>**

Colony forming units for total bacterial count were counted by plating on plate count agar medium and incubated at 30°C for three to five days (APHA, 1992). Total molds and yeasts were counted on oxytetracycline glucose yeast extract agar medium according to Oxoid, (1998). psychrophilic and spore forming bacteria count according to (FDA, 2002).

### 2.3 Statistical analysis<sup>26</sup>

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was  $P \leq 0.05$ .

The experimental data<sup>26</sup> obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations:

like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_j x_j + \sum \beta_{jj} x_j^2 + \sum \beta_{ij} x_i x_j$ , where  $y$  is the response,  $x_i$  and  $x_j$  are the uncoded independent variables (factors), and  $\beta_0$ ,  $\beta_i$  &  $\beta_j$ ,  $\beta_{ii}$  &  $\beta_{jj}$  and  $\beta_{ij}$  are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs. In this the Total bacterial count was the response and the dependent two factors were the Storage time and the gamma-irradiation Dose given to the sliced chicken.

### 3 RESULT AND DISCUSSION

The result of statistical Analysis are shown below:

*Table 1. shows the fit summary the models*

Response 1      total bacteria Transform:      None  
 \*\*\* WARNING: The Quartic Model and higher are Aliased! \*\*\*

Summary (detailed tables shown below)

	Sequential	Lack of Fit	Adjusted	Predicted	
Source	p-value	p-value	R-Squared	R-Squared	
Linear	0.0135		0.3264	-0.1709	
2FI	0.1682		0.3668	-0.2331	
Quadratic	0.0043		0.6673	-0.1030	
<u>Cubic</u>	<u>0.0308</u>		<u>0.8250</u>	<u>-0.1268</u>	<u>Suggested</u>
Quartic	0.0983		0.9071	-0.6251	Aliased

*Table 2. Shows the model sum of square*

Sequential Model Sum of Squares [Type I]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
<u>Mean vs Total</u>	<u>9.822E+008</u>	<u>1</u>	<u>9.822E+008</u>			<u>Suggested</u>
Linear vs Mear	3.543E+009	2	1.771E+009	5.60	0.0135	
2FI vs Linear	6.190E+008	1	6.190E+008	2.08	0.1682	
Quadratic vs 2	2.569E+009	2	1.284E+009	8.22	0.0043	
<u>Cubic vs Quad</u>	<u>1.365E+009</u>	<u>4</u>	<u>3.413E+008</u>	<u>4.16</u>	<u>0.0308</u>	<u>Suggested</u>
Quartic vs Cub	5.597E+008	4	1.399E+008	3.21	0.0983	Aliased
Residual	2.615E+008	6	4.359E+007			
Total	9.899E+009	20	4.950E+008			

Table 3. Model summary Statistics

Model Summary Statistics						
Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	17779.62	0.3973	0.3264	-0.1709	1.044E+010	
2FI	17238.97	0.4668	0.3668	-0.2331	1.100E+010	
Quadratic	12496.37	0.7548	0.6673	-0.1030	9.835E+009	
<u>Cubic</u>	<u>9062.12</u>	<u>0.9079</u>	<u>0.8250</u>	<u>-0.1268</u>	<u>1.005E+010</u>	<u>Suggested</u>
Quartic	6601.97	0.9707	0.9071	-0.6251	1.449E+010	Aliased

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	8.096E+009	9	8.995E+008	10.95	0.0004	significant
A-Storage Pe	2.596E+008	1	2.596E+008	3.16	0.1058	
B-GID	1.192E+008	1	1.192E+008	1.45	0.2561	
AB	1.825E+008	1	1.825E+008	2.22	0.1669	
A <sup>2</sup>	7.192E+008	1	7.192E+008	8.76	0.0143	
B <sup>2</sup>	5.032E+007	1	5.032E+007	0.61	0.4519	
A <sup>2</sup> B	1.711E+008	1	1.711E+008	2.08	0.1795	
AB <sup>2</sup>	3.168E+007	1	3.168E+007	0.39	0.5484	
A <sup>3</sup>	1.228E+009	1	1.228E+009	14.95	0.0031	
B <sup>3</sup>	8.643E+006	1	8.643E+006	0.11	0.7523	
Residual	8.212E+008	10	8.212E+007			
Cor Total	8.917E+009	19				

The Model F-value of 10.95 implies the model is significant. There is only a 0.04% chance that an F-value this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant.

Table 5. ANNOVA Summary

Std. Dev.	9062.12	R-Squared	0.9079
Mean	7007.80	Adj R-Squared	0.8250
C.V. %	129.31	Pred R-Square	-0.1268
PRESS	1.005E+010	Adeq Precisor	14.752

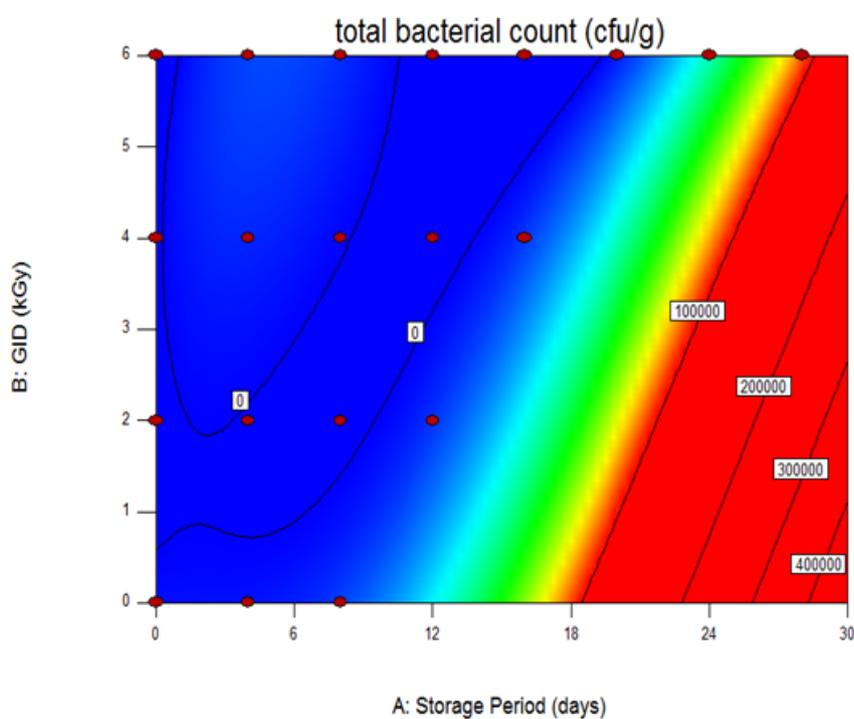
A negative "Pred R-Squared" implies that the overall mean is a better predictor of your response than the current model.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 14.752 indicates an adequate signal. This model can be used to navigate the design space.

The developed Fit Suggested required Model:

**Final Equation in Terms of Actual Factors:**

$$\begin{aligned}
 \text{total bacterial count} = & \\
 & +1275.78336 \\
 & +288.92694 * \text{Storage Period} \\
 & -2830.03834 * \text{GID} \\
 & +186.58336 * \text{Storage Period} * \text{GID} \\
 & -126.94696 * \text{Storage Period}^2 \\
 & +1131.28538 * \text{GID}^2 \\
 & -90.82060 * \text{Storage Period}^2 * \text{GID} \\
 & +102.35754 * \text{Storage Period} * \text{GID}^2 \\
 & +21.73834 * \text{Storage Period}^3 \\
 & -136.60468 * \text{GID}^3
 \end{aligned}$$



*Fig 1. Shows the Contour Graph for the developed Model.*

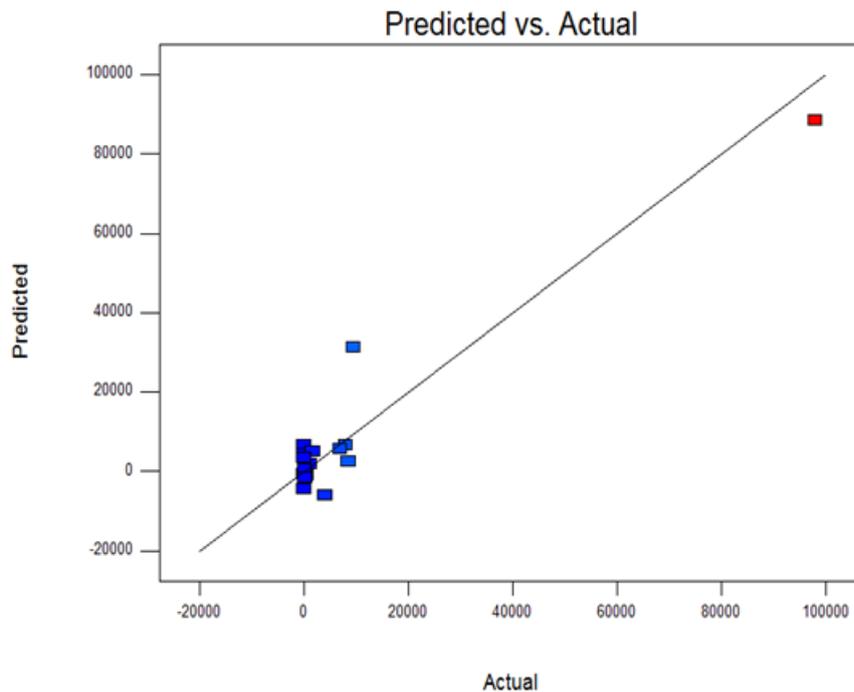


Fig 2. Shows the Graph plotted between Predicted value and the Actual values for the suggested model

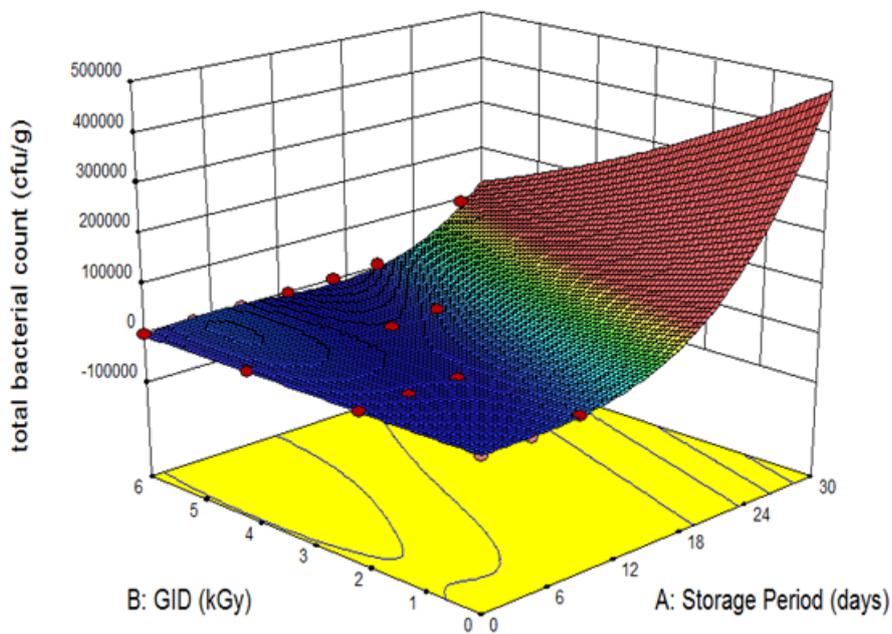


Fig 3. Shows the 3-D Graph Plotted between TBC, GID and SP. For the developed model.

## 4 CONCLUSION

Thus we get a most fitted model for the function of total bacterial count (TBC) with gamma Irradiation dose (GID) and storage period (SP) as the two variants, with  $R^2 = 0.9079$ , F value 10.95 and P value 0.0308, the suggested model is more significant for the given design data set.

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#### **AUTHOR'S BIOGRAPHY**

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



## Modeling of Spore Forming Bacterial Population on the Sliced Chicken as a Function of Period of Storage and Gamma-Irradiation Dose Given

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This paper deals with the developing the most suggested model with  $R^2 = 0.9092$  for Total Spore forming bacterial count as a function of the irradiation dose and the storage period for a sliced chicken meat.

**KEYWORDS:** Irradiation, Radiation, Modeling, Cobalt-60, Radiolysis, Design Expert Software 8.0.

### 1 INTRODUCTION

Poultry carcasses are commonly contaminated with en-teric pathogens such as Salmonella, Campylobacter and *Listeria monocytogenes* (Jacobsreitsma et al., 1994; Murphy et al., 2004); the possibility of cross contamination of poultry carcasses post slaughter is high. Decontamination of poultry carcasses is therefore desirable. Various decontamination technologies have been proposed including the use of various chemical agents such as alkali (Rodriguez et al., 1996), physical methods such as steam treatment (James et al., 2007) and biological control with bacteriophages (Carvalho et al., 2010), but only treat-ment with water supplemented with chlorine or a chlorine-ting agent is used commercially. The effects of such decontaminating treatments are limited (Oyarzabal, 2005; Russell and Axtell, 2005).

The term "radiation chemistry" refers to the chemical reactions that occur as a result of the absorption of ionizing radiation. In the context of food irradiation, the reactants are the chemical constituents of the food and initial radiolysis products that may undergo further chemical reactions. The chemistry involved in the irradiation of foods has been the subject of numerous studies over the years and scientists have compiled a large body of data regarding the effects of ionizing radiation on different foods under various conditions of irradiation. The basic principles are well understood and provide the basis for extrapolation and generalization from data obtained in specific foods irradiated under specific conditions to draw conclusions regarding foods of a similar type irradiated under different, yet related, conditions. The types and amounts of products generated by radiation induced chemical reactions ["radiolysis products"] depend on both the chemical constituents of the food and on the specific conditions of irradiation.

The principles of radiation chemistry also govern the extent of change, if any, in both the nutrient levels and the microbial loads of irradiated foods.

Factors Affecting the Radiation Chemistry of Foods- Apart from the chemical composition of the food itself, the specific conditions of irradiation that are most important in considering the radiation chemistry of a given food include the radiation dose, the physical state of the food (e.g., solid or frozen versus liquid or non-frozen state, dried versus hydrated state), and the ambient atmosphere (e.g., air, reduced oxygen, and vacuum). The temperature at which irradiation is conducted can also be a factor, with more radiation-induced changes occurring with increasing temperature. Temperature is less important, however, than the physical state of the food. The amounts of radiolysis products generated in a particular food are directly proportional to the radiation dose. Therefore, one can extrapolate from data obtained at high radiation doses to draw conclusions regarding the effects at lower doses.

The radiation chemistry of food is strongly influenced by the physical state of the food. If all other conditions, including dose and ambient atmosphere, are the same, the extent of chemical change that occurs in a particular food in the frozen state is less than the change that occurs in the non-frozen state. This is because of the reduced mobility, in the frozen state, of the initial radiolysis products, which will tend to recombine rather than diffuse and react with other food components. Likewise, and for similar reasons, if all other conditions are the same, the extent of chemical change that occurs in the dehydrated state is less than the change that occurs in the fully hydrated state.

The formation of radiolysis products in a given food also is affected by the ambient atmosphere. Irradiation in an atmosphere of high oxygen content generally produces both a greater variety, and greater amounts, of radiolysis products in the food than would be produced in an atmosphere of lower oxygen content. This is because irradiation initiates certain oxidation reactions that occur with greater frequency in foods with high fat content.

With few exceptions, the radiolysis products generated in a particular food are the same or very similar to the products formed in other types of food processing or under common storage conditions. These radiolysis products are also typically formed in very small amounts. Radiation-induced chemical changes, if sufficiently large, however, may cause changes in the organoleptic properties of the food. Because food processors want to avoid undesirable effects on taste, odor, color, or texture, there is an incentive to minimize the extent of these chemical changes in food. Thus, the doses used to achieve a given technical effect (e.g., inhibition of sprouting, reduction in microorganisms) must be selected carefully to both achieve the intended effect and minimize undesirable chemical changes.

Typically, the dose or dose range selected will be the lowest dose practical in achieving the desired effect. Irradiation also is often conducted under reduced oxygen levels or on food held at low temperature or in the frozen state.

In general, during inactivation of microorganisms on surfaces, the rate of inactivation is inversely proportional to the initial cell concentration (Shintani, 2000). Food irradiation is being considered an important tool, in ensuring safety and extending shelf-life of fresh meat and poultry (Yoon, 2003). Thus irradiation can eliminate food-borne pathogenic microorganisms in meat. Furthermore, the use of gamma irradiation as a safety technological treatment in food preservation has now become legally accepted in many countries of the world (Abdel-Daium, 2007).

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the total Spore Forming bacterial count as a function of the irradiation dose and the storage period of irradiated sliced chicken meat.

## **2 MATERIALS AND METHODS**

<sup>26</sup>Sliced chicken were purchased from local market (Benha, Qaliohia governorate, Egypt). All samples were transported to the laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts spore forming bacteria. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

### **2.1 Gamma irradiation treatments<sup>26</sup>**

Four bags from each of sliced chicken were gamma irradiated at 0, 2, 4, and 6 kGy doses using cobalt-60 gamma chamber (1.367 kGy/h) in Cyclotron Project, Nuclear Research Center Atomic Energy Authority, Inshas, Cairo, Egypt. After irradiation, all samples were stored at 4±1°C.

### **2.2 Microbial analysis<sup>26</sup>**

Spore forming bacteria count according to (FDA, 2002).

### **2.3 Statistical analysis<sup>26</sup>**

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was  $P \leq 0.05$ .

The experimental data<sup>26</sup> obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations:

like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_j x_j + \sum \beta_{jj} x_j^2 + \sum \beta_{ij} x_i x_j$ , where  $y$  is the response,  $x_i$  and  $x_j$  are the uncoded independent variables (factors), and  $\beta_0$ ,  $\beta_i$  &  $\beta_j$ ,  $\beta_{ii}$  &  $\beta_{jj}$  and  $\beta_{ij}$  are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs. In this the Total Spore forming bacterial count was the response and the dependent two factors were the Storage time and the gamma-irradiation Dose given to the sliced chicken.

### 3 RESULT AND DISCUSSION

The result of statistical Analysis are shown below:

*Table 1. shows the fit summary the models*

Response	1	Spore formir Transform:	None		
*** WARNING: The Quartic Model and higher are Aliased! ***					
Summary (detailed tables shown below)					
Source	Sequential p-value	Lack of Fit p-value	Adjusted R-Squared	Predicted R-Squared	
Linear	0.0195		0.2966	-0.2306	
2FI	0.2241		0.3206	-0.3175	
Quadratic	0.0056		0.6298	-0.2218	
<u>Cubic</u>	<u>0.0177</u>		<u>0.8276</u>	<u>-0.1223</u>	<u>Suggested</u>
Quartic	0.0514		0.9278	-0.2326	Aliased

*Table 2. Shows the model sum of square*

Sequential Model Sum of Squares [Type I]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
<u>Mean vs Total</u>	<u>1.712E+007</u>	<u>1</u>	<u>1.712E+007</u>			<u>Suggested</u>
Linear vs Mear	3.233E+007	2	1.617E+007	5.01	0.0195	
2FI vs Linear	4.989E+006	1	4.989E+006	1.60	0.2241	
Quadratic vs 2	2.612E+007	2	1.306E+007	7.68	0.0056	
<u>Cubic vs Quad</u>	<u>1.588E+007</u>	<u>4</u>	<u>3.969E+006</u>	<u>5.01</u>	<u>0.0177</u>	<u>Suggested</u>
Quartic vs Cub	5.929E+006	4	1.482E+006	4.47	0.0514	Aliased
Residual	1.988E+006	6	3.314E+005			
Total	1.044E+008	20	5.218E+006			

Table 3. Model summary Statistics

Model Summary Statistics						
Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	1797.09	0.3707	0.2966	-0.2306	1.074E+008	
2FI	1766.23	0.4278	0.3206	-0.3175	1.149E+008	
Quadratic	1303.66	0.7273	0.6298	-0.2218	1.066E+008	
<u>Cubic</u>	<u>889.81</u>	<u>0.9092</u>	<u>0.8276</u>	<u>-0.1223</u>	<u>9.790E+007</u>	<u>Suggested</u>
Quartic	575.64	0.9772	0.9278	-0.2326	1.075E+008	Aliased

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	7.932E+007	9	8.813E+006	11.13	0.0004	significant
A-storage pe.	2.716E+006	1	2.716E+006	3.43	0.0937	
B-GID	1.200E+006	1	1.200E+006	1.52	0.2464	
AB	1.592E+006	1	1.592E+006	2.01	0.1865	
A <sup>2</sup>	7.339E+006	1	7.339E+006	9.27	0.0124	
B <sup>2</sup>	83041.84	1	83041.84	0.10	0.7527	
A <sup>2</sup> B	1.600E+006	1	1.600E+006	2.02	0.1855	
AB <sup>2</sup>	17300.05	1	17300.05	0.022	0.8854	
A <sup>3</sup>	1.395E+007	1	1.395E+007	17.62	0.0018	
B <sup>3</sup>	69003.04	1	69003.04	0.087	0.7739	
Residual	7.918E+006	10	7.918E+005			
Cor Total	8.724E+007	19				

The Model F-value of 11.13 implies the model is significant. There is only a 0.04% chance that an F-value this large could occur due to noise.

Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A<sup>2</sup>, A<sup>3</sup> are significant model terms.

Values greater than 0.1000 indicate the model terms are not significant.

Table 5. ANNOVA Summary

Std. Dev.	889.81	R-Squared	0.9092
Mean	925.20	Adj R-Squared	0.8276
C.V. %	96.18	Pred R-Square	-0.1223
PRESS	9.790E+007	Adeq Precisor	15.492

A negative "Pred R-Squared" implies that the overall mean is a better predictor of your response than the current model.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 15.492 indicates an adequate signal. This model can be used to navigate the design space.

The developed equation in terms of coded factor:

#### Final Equation in Terms of Coded Factors:

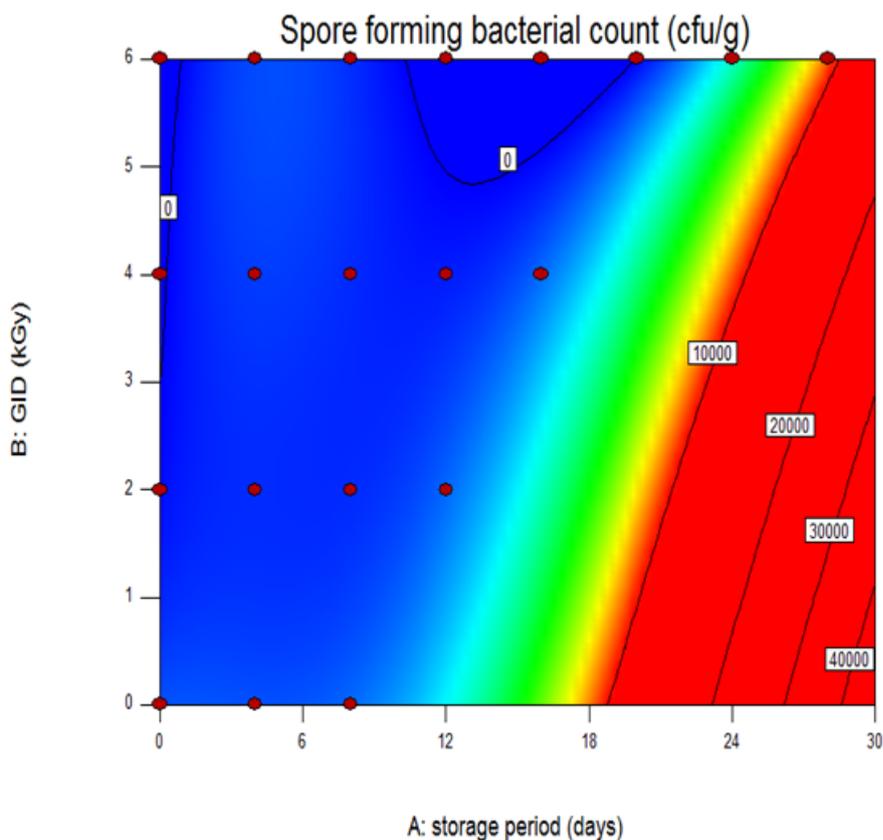
$$\begin{aligned} \text{Spore forming bacterial count} = & \\ & +1501.81 \\ & +6844.32 * A \\ & -2455.13 * B \\ & -8088.21 * AB \\ & +13155.88 * A^2 \\ & +525.45 * B^2 \\ & -5928.82 * A^2B \\ & +322.92 * AB^2 \\ & +7819.60 * A^3 \\ & -329.56 * B^3 \end{aligned}$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The developed Fit Suggested required Model:

**Final Equation in Terms of Actual Factors:**

$$\begin{aligned} \text{Spore forming bacterial count} = & \\ & +821.60580 \\ & +36.32223 * \text{storage period} \\ & -563.16208 * \text{GID} \\ & +69.41304 * \text{storage period} * \text{GID} \\ & -19.44036 * \text{storage period}^2 \\ & +132.35734 * \text{GID}^2 \\ & -8.78344 * \text{storage period}^2 * \text{GID} \\ & +2.39202 * \text{storage period} * \text{GID}^2 \\ & +2.31692 * \text{storage period}^3 \\ & -12.20606 * \text{GID}^3 \end{aligned}$$



*Fig 1. Shows the Contour Graph for the developed Model.*

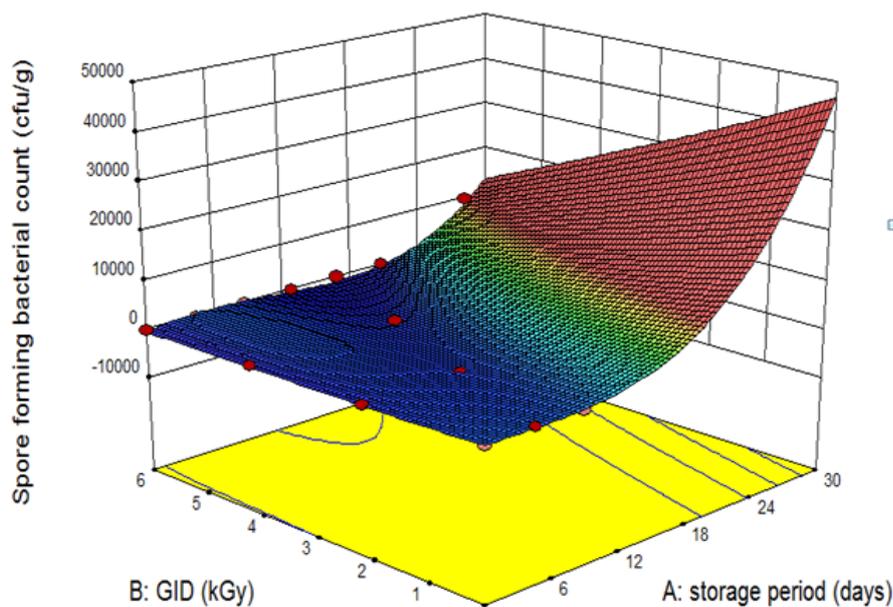


Fig 2. Shows the 3-D Graph Plotted between TSFB, GID and SP. For the developed model.

#### 4 CONCLUSION

Thus we get a most fitted model for the function of total spore forming bacterial (TSFB) with gamma Irradiation dose (GID) and storage period (SP) as the two variants, with  $R^2 = 0.9092$ , F value 11.13 and P value  $<0.004$ , the suggested model is more significant for the given design data set.

#### ACKNOWLEDGEMENT

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**AUTHOR'S BIOGRAPHY**

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



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*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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Typically, the dose or dose range selected will be the lowest dose practical in achieving the desired effect. Irradiation also is often conducted under reduced oxygen levels or on food held at low temperature or in the frozen state.

In general, during inactivation of microorganisms on surfaces, the rate of inactivation is inversely proportional to the initial cell concentration (Shintani, 2000). Food irradiation is being considered an important tool, in ensuring safety and extending shelf-life of fresh meat and poultry (Yoon, 2003). Thus irradiation can eliminate food-borne pathogenic microorganisms in meat. Furthermore, the use of gamma irradiation as a safety technological treatment in food preservation has now become legally accepted in many countries of the world (Abdel-Daium, 2007).

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the total Yeast and mold count as a function of the irradiation dose and the storage period of irradiated sliced chicken meat.

## 2 MATERIALS AND METHODS

<sup>26</sup>Sliced chicken were purchased from local market (Benha, Qalibia governorate, Egypt). All samples were transported to the laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts for counts of total bacteria, psychophilic bacteria, spore forming bacteria, total molds and yeasts. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

### 2.1 Gamma irradiation treatments<sup>26</sup>

Four bags from each of sliced chicken were gamma irradiated at 0, 2, 4, and 6 kGy doses using cobalt-60 gamma chamber (1.367 kGy/h) in Cyclotron Project, Nuclear Research Center Atomic Energy Authority, Inshas, Cairo, Egypt. After irradiation, all samples were stored at 4±1°C.

### 2.2 Microbial analysis<sup>26</sup>

Total molds and yeasts were counted on oxytetracycline glucose yeast extract agar medium according to Oxoid, (1998).

### 2.3 Statistical analysis<sup>26</sup>

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was  $P \leq 0.05$ .

The experimental data<sup>26</sup> obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations: like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_{ij} x_i x_j + \sum \beta_{ijj} x_i x_j^2 + \sum \beta_{ijij} x_i x_j x_i x_j$ , where  $y$  is the response,  $x_i$  and  $x_j$  are the uncoded independent variables (factors), and  $\beta_0, \beta_i$  &  $\beta_{ij}$ ,  $\beta_{ii}$  &  $\beta_{jj}$  and  $\beta_{ijj}$  are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs. In this the Total Yeast and Mold count was the response and the dependent two factors were the Storage time and the gamma-irradiation Dose given to the sliced chicken.

### 3 RESULT AND DISCUSSION

The result of statistical Analysis are shown below:

*Table 1. Shows the Fit Summary the Models*

Response	1	Yeast and m	Transform:	None	
*** WARNING: The Quartic Model and higher are Aliased! ***					
Summary (detailed tables shown below)					
Source	Sequential p-value	Lack of Fit p-value	Adjusted R-Squared	Predicted R-Squared	
Linear	0.0203		0.2935	-0.2246	
2FI	0.2695		0.3061	-0.3398	
Quadratic	0.0047		0.6316	-0.2123	
Cubic	<u>0.0109</u>		<u>0.8453</u>	<u>-0.0161</u>	Suggested
Quartic	0.0203		0.9535	0.1751	Aliased

*Table 2. Shows the model sum of square*

Sequential Model Sum of Squares [Type I]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	<u>5.561E+008</u>	<u>1</u>	<u>5.561E+008</u>			Suggested
Linear vs Mean	1.711E+009	2	8.557E+008	4.95	0.0203	
2FI vs Linear	2.223E+008	1	2.223E+008	1.31	0.2695	
Quadratic vs 2	1.456E+009	2	7.278E+008	8.07	0.0047	
Cubic vs Quad	<u>8.839E+008</u>	<u>4</u>	<u>2.210E+008</u>	<u>5.83</u>	<u>0.0109</u>	Suggested
Quartic vs Cub	3.104E+008	4	7.761E+007	6.81	0.0203	Aliased
Residual	6.838E+007	6	1.140E+007			
Total	5.208E+009	20	2.604E+008			

Table 3. Model summary Statistics

Model Summary Statistics						
Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	13152.09	0.3679	0.2935	-0.2246	5.697E+009	
2FI	13034.38	0.4157	0.3061	-0.3398	6.233E+009	
Quadratic	9496.94	0.7286	0.6316	-0.2123	5.640E+009	
<u>Cubic</u>	<u>6154.83</u>	<u>0.9186</u>	<u>0.8453</u>	<u>-0.0161</u>	<u>4.727E+009</u>	<u>Suggested</u>
Quartic	3375.86	0.9853	0.9535	0.1751	3.838E+009	Aliased

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	4.273E+009	9	4.748E+008	12.53	0.0002	significant
A-storage pe.	1.892E+008	1	1.892E+008	5.00	0.0494	
B-GID	1.406E+008	1	1.406E+008	3.71	0.0829	
AB	1.534E+008	1	1.534E+008	4.05	0.0719	
A <sup>2</sup>	4.921E+008	1	4.921E+008	12.99	0.0048	
B <sup>2</sup>	3.674E+007	1	3.674E+007	0.97	0.3480	
A <sup>2</sup> B	1.385E+008	1	1.385E+008	3.66	0.0849	
AB <sup>2</sup>	2.694E+007	1	2.694E+007	0.71	0.4188	
A <sup>3</sup>	8.185E+008	1	8.185E+008	21.61	0.0009	
B <sup>3</sup>	1.787E+005	1	1.787E+005	4.717E-003	0.9466	
Residual	3.788E+008	10	3.788E+007			
Cor Total	4.652E+009	19				

The Model F-value of 12.53 implies the model is significant. There is only a 0.02% chance that an F-value this large could occur due to noise.

Table 5. ANNOVA Summary

Std. Dev.	6154.83	R-Squared	0.9186
Mean	5273.00	Adj R-Squared	0.8453
C.V. %	116.72	Pred R-Square	-0.0161
PRESS	4.727E+009	Adeq Precisor	16.229

A negative "Pred R-Squared" implies that the overall mean is a better predictor of your response than the current model.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 16.229 indicates an adequate signal. This model can be used to navigate the design space.

The developed equation in terms of coded factor:

**Final Equation in Terms of Coded Factors:**

$$\begin{aligned} \text{Yeast and mold count} = & \\ & +9383.34 \\ & +57132.14 * A \\ & -26569.77 * B \\ & -79370.51 * AB \\ & +1.077E+005 * A^2 \\ & +11051.71 * B^2 \\ & -55157.74 * A^2B \\ & +12743.67 * AB^2 \\ & +59902.35 * A^3 \\ & +530.36 * B^3 \end{aligned}$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The developed Fit Suggested required Model:

**Final Equation in Terms of Actual Factors:**

$$\begin{aligned} \text{Yeast and mold count} = & \\ & +210.09370 \\ & +212.31684 * \text{storage period} \\ & +872.66945 * \text{GID} \\ & +121.28049 * \text{storage period} * \text{GID} \\ & -74.76771 * \text{storage period}^2 \\ & -364.78181 * \text{GID}^2 \\ & -81.71516 * \text{storage period}^2 * \text{GID} \\ & +94.39755 * \text{storage period} * \text{GID}^2 \\ & +17.74884 * \text{storage period}^3 \\ & +19.64289 * \text{GID}^3 \end{aligned}$$

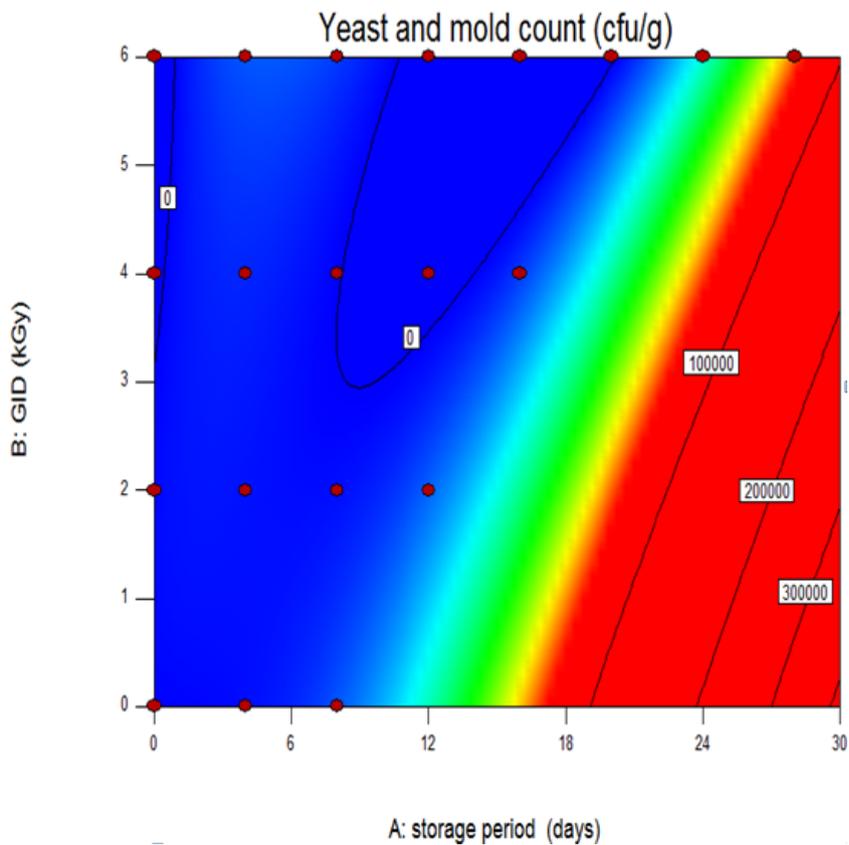


Fig 1. Shows the Contour Graph for the developed Model.

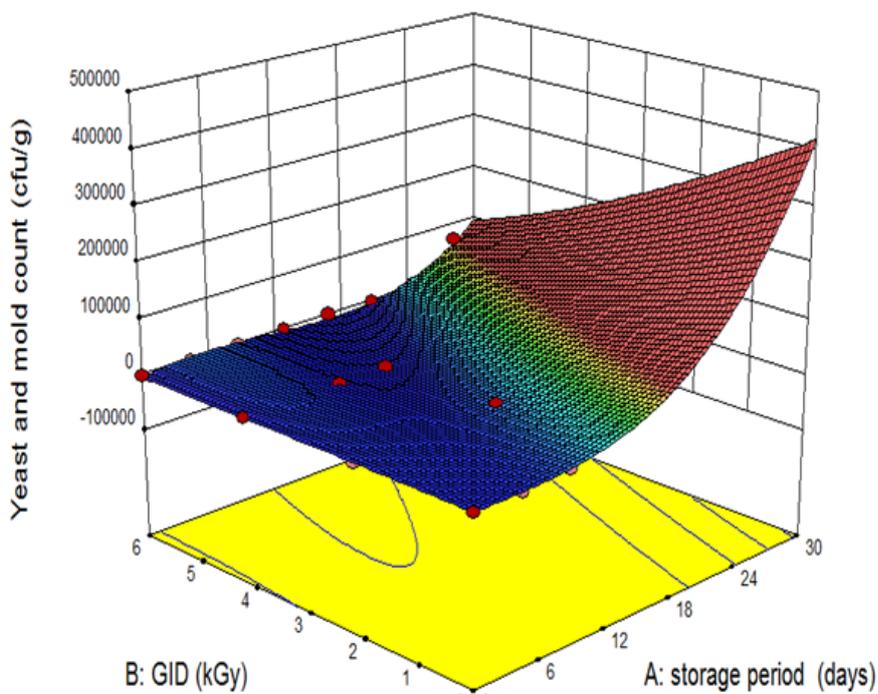


Fig 2. Shows the 3-D Graph Plotted between YMC, GID and SP. For the developed model.

#### **4 CONCLUSION**

Thus we get a most fitted model for the function of total yeast and mold (YMC) with gamma Irradiation dose (GID) and storage period (SP) as the two variants, with  $R^2 = 0.9186$ , F value 12.53 and P value  $<0.0002$ , the suggested model is more significant for the given design data set.

#### **ACKNOWLEDGEMENT**

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#### AUTHOR'S BIOGRAPHY

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



## Modeling of Total Psychrophilic Bacterial Population on the Sliced Chicken as a Function of Period of Storage and Time of Cold Atmospheric Plasma Given

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This paper deals with the developing the most suggested model with  $R^2 = 0.8734$  for Total Psychrophilic bacterial count as a function of the cold plasma treatment time and the storage period for a sliced chicken meat.

**KEYWORDS:** Cold Atmospheric Plasma, Molecular oxygen, Modeling, Ionized gas, Design Expert Software 8.0.

### 1 INTRODUCTION

Poultry carcasses are commonly contaminated with en-teric pathogens such as Salmonella, Campylobacter and *Listeria monocytogenes* (Jacobsreitsma et al., 1994; Murphy et al., 2004); the possibility of cross contamination of poultry carcasses post slaughter is high. Decontamination of poultry carcasses is therefore desirable. Various decontamination technologies have been proposed including the use of various chemical agents such as alkali (Rodriguez et al., 1996), physical methods such as steam treatment (James et al., 2007) and biological control with bacteriophages (Carvalho et al., 2010), but only treat-ment with water supplemented with chlorine or a chlorine-ting agent is used commercially. The effects of such decontaminating treatments are limited (Oyarzabal, 2005; Russell and Axtell, 2005).

#### 1.1 PLASMA SCIENCE

##### 1.1.1 PLASMA- DEFINITION, PHYSICS AND CHEMISTRY

In 1922, the American scientist Irving Langmuir proposed that the electrons, ions and neutrals in an ionized gas could be considered as corpuscular material entrained in some kind of fluid medium and termed this entraining medium "*plasma*", similar to the plasma, introduced by the Czech physiologist Jan Evangelista Purkinje to denote the clear fluid which remains after removal of all the corpuscular material in blood. However, it emerged that there was no "fluid medium" entraining the electrons, ions, and neutrals in an ionized gas (Bellan 2006), nevertheless the name prevailed. The term "*plasma*" refers to a partially or wholly ionized gas composed essentially of photons, ions and free electrons as well as atoms in their fundamental or excited states possessing a net neutral charge. The plasma possesses a net neutral charge because the number of positive charge carriers is equal to the number of negative ones (Kudra and Mujumdar 2009). Electrons and photons are usually designated as "light" species in contrast to the rest of the constituents designated as "heavy" species. Due to its unique properties plasma is often referred to as the fourth state of matter according to a scheme expressing an increase in the energy level from solid to liquid to gas and ultimately to plasma.

##### 1.1.2 TYPES OF PLASMA

Two classes of plasma, namely thermal and NTP can be distinguished on the basis of conditions in which they are generated. This classification of plasma is based on the relative energetic levels of electrons and heavy species of the plasma. NTP (near ambient temperatures of 30-60oC) is obtained at atmospheric or reduced pressures (vacuum) and requires less

power. NTPs are characterised by an electron temperature much above that of the gas (macroscopic temperature) and consequently do not present a local thermodynamic equilibrium. NTP can be generated by an electric discharge in a gas at lower pressure or using microwaves. Typical illustrations for plasma generation at atmospheric pressure include the corona discharge, Dielectric barrier discharges (DBD), Radio-frequency plasmas (RFP) and the gliding arc discharge. In contrast, thermal plasmas are generated at higher pressures, require high power, and an almost thermal equilibrium exists between the electrons and the heavy species. Plasma generation at atmospheric pressure is of interest, both technically and industrially for the food industries because this does not require extreme conditions.

## 1.2 ACTION OF PLASMA ON MICROORGANISMS

### 1.2.1 ACTION ON CELL COMPONENTS AND FUNCTIONS

The use of sterilizing properties of plasma was first introduced towards the end of 60s, patented in 1968 (Menashi 1968) and first works with plasma made from oxygen were proposed in 1989. Thereafter, considerable research has been performed on the mechanism of microbial inactivation by plasma agents. The plasma agents contribute to the lethal action by interacting with the biological material. Nelson and Berger (1989) have shown that O<sub>2</sub> plasma could be a very efficient biocidal against bacteria. Plasma treatment can effectively inactivate a wide range of micro-organisms including spores (Kelly-Wintenberg et al. 1999; Feichtinger et al. 2003; Lee et al. 2006) and viruses (Terrier et al. 2009). Effect of plasma can be quite selective, meaning tuneable between damage to pathogenic organisms without damage to the host, or activation of different pathways in different organisms (Dobrynin et al. 2009). Low-pressure oxygen plasma has been shown to degrade lipids, proteins and DNA of cells (Mogul et al. 2003). The reactive species in plasma have been widely associated to the direct oxidative effects on the outer surface of microbial cells. As an example, commonly used oxygen and nitrogen gas plasma are excellent sources of reactive oxygen-based and nitrogen-based species, such as O•, O<sup>2</sup>, O<sup>3</sup>, OH•, NO•, NO<sub>2</sub> etc.

Atomic oxygen is potentially a very effective sterilizing agent, with a chemical rate constant for oxidation at room temperature of about 106 times that of molecular oxygen (Critzler et al. 2007). These act on the unsaturated fatty acids of the lipid bilayer of the cell membrane, thereby impeding the transport of bio-molecules across it. The double bonds of unsaturated lipids are particularly vulnerable to ozone attack (Guzel-Seydim et al. 2004). Membrane lipids are assumed to be more significantly affected by the reactive oxygen species (ROS) due to their location along the surface of bacterial cell, which allows them to be bombarded by these strong oxidizing agents (Montie et al. 2002). The proteins of the cells and the spores are equally vulnerable to the action of these species, causing denaturation and cell leakage. Oxidation of amino acids and nucleic acids may also cause changes that result in microbial death or injury (Critzler et al. 2007). Micro-organisms in plasma are exposed to an intense bombardment by the radicals most likely provoking surface lesions that the living cell cannot repair sufficiently faster. This may partially explain the observations wherein cells are in many cases destroyed very quickly. This process is termed "etching" (Pelletier 1992). The cell wall rupture has been additionally attributed by Laroussi et al., (2003) and Mendis et al., (2002) to electrostatic forces due to accumulation of charges at the outer surface of cell membranes. The morphological changes in *E. coli* cells treated with atmospheric plasma at 75W for 2 min as observed under an electron microscope by (Hong et al. 2009), clearly revealed that the treated cells had severe cytoplasmic deformations and leakage of bacterial chromosome. These observations demonstrate the loss of viability of bacterial cells after plasma treatment. An analogy between plasma and pulsed electric field has also been drawn to explain the action of plasma on the membranes (Pothakamury et al. 1995; Spilimbergo et al. 2003). It is well established that electroporation of membranes is induced by pulsed electric fields and it appears that plasma acts on similar lines inducing perforations in the membranes of micro-organisms (Sale and Hamilton 1967; Pothakamury et al. 1995; Wouters and Smelt 1997). In addition to generating pores, humid air plasma additionally provokes a marked acidification of the medium (Moreau et al. 2005; Moreau et al. 2007).

### 1.2.2 ROLE OF UV PHOTONS AND CHARGED PARTICLES

The production of UV photons of different wavelengths has been proposed to be involved in dimerizing the thymine bases of DNA including that of spores (Munakata et al. 1991). The role of UV photons in bacterial death when they are submitted to a plasma treatment was reviewed in detail by (Boudam et al. 2006). Recently, by exclusion of reactive particles and spectral fractions of UV radiation from access to the spores Roth et al., (2010) revealed that UV-C radiation is the most effective inactivation agent in the plasma. Ultraviolet (UV) photons play a less important role in atmospheric pressure glow discharge (APGD) because they are easily absorbed by gas atoms and molecules at atmospheric pressure (Vleugels et al. 2005). The role of the charged particles in the bacterial inactivation process was recently investigated by Lu *et al.* (2009). Their work revealed that the charged particles play a minor role in the inactivation process when He/N<sub>2</sub> (3%) is used as working gas than when He/O<sub>2</sub> (3%) is used. Also, they concluded that heat and UV play no or minor roles in the inactivation

process. Similar results were earlier obtained by (Perni et al. 2007) who interplayed bacterial inactivation kinetics with optical emission spectroscopy, and identified oxygen atoms as major contributor in plasma inactivation with minor contributions from UV photons, OH radicals, singlet oxygen metastables and nitric oxide. Thus, a contradiction over the role of UV photons in plasma exists and future studies must be directed to get a clear picture.

### **1.2.3 EFFECT OF PROCESS PARAMETERS**

The concentrations in which the plasma agents occur in plasma depend greatly on the device set-up (reactor geometry), operating conditions (gas pressure, type, flow, frequency and power of plasma excitation) and gas composition which affect their efficacy in a process when employed. To cite an example, the destructive efficiency of various gas plasma sources and temperatures on *Bacillus spp.* spores were compared by (Hury et al. 1998). This group demonstrated that oxygen-based plasma is more efficient than pure argon plasma. Another deciding criterion is whether the substrate to be sterilized is in direct contact with the plasma (*Direct Exposure*) or located remote from it (*Remote Exposure*) (Moisan et al. 2001; Laroussi 2005; Boudam et al. 2006). If exposed remotely, the quantum of heat transmitted to a sample is reduced, the charged particles do not play a role since they recombine before reaching the sample, and many of the short-lived neutral reactive species also do not reach the sample. Since, the components of the plasma are reactive and self-quenching, with a relatively short half-life, decreased time of flight would be expected to be one of the major factors in antimicrobial efficacy in this case (Niemira and Sites 2008). By varying the process parameters involved in plasma generation, a multitude of mechanisms can be actuated which may act individually or synergistically.

Nevertheless, the details of interaction of the different plasma agents with the different components of bacterial cells or spores are currently very limited. The interactions which occur between plasma agents and biological materials, ultimately leading to sterilization are still under investigation.

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the total Psychrophilic bacterial count as a function of the cold plasma treatment time and the storage period of treated sliced chicken meat.

## **2 MATERIALS AND METHODS**

<sup>26</sup>Sliced chicken were purchased from local market (Benha, Qaliobia governorate, Egypt). All samples were transported to our laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts for counts of total bacteria, psychrophilic bacteria, spore forming bacteria, total molds and yeasts. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

### **2.1 PLASMA TREATMENTS CHARACTER OF EXPOSURE MACHINE**

The plasma generator consisted of a negative dc source, a Blumlein-type pulse-forming network (E-PFN), and a dynamic spark gap switch. A triggered spark gap switch was used as a closing switch of E-PFN. E-PFN had four stages of LC ladder, which were composed of 5 nF of capacitor and 3 μH of inductor. The characteristic impedance (2VL/C) and the pulse width (2NVLC) of E-PFN, calculated from capacitance (C) and inductance (L) of the LC ladder, and number (N) of LC ladder stages were approximately 49 Ω and 1.0 μs, respectively.

A charging resistance value of 50 kΩ was chosen in the present case which corresponds to a charging RC time constant of 1 ms, which is 40 times faster compared to the repetition rate of the pulse. A schematic of the pulsed atmospheric-pressure plasma jet (PAPPJ) device for generating high voltage pulsed, cold atmospheric plasma jets is shown in Figure 1. The high voltage (HV) wire electrode, which is made of a copper wire, is inserted into a hollow barrel of a syringe. The distance between the tip of the HV electrode and the nozzle is 0.5 cm. When HV pulsed, DC voltage (amplitudes up to 25 kV, repetition rate up to 25 Hz), was applied to the HV electrode and helium gas was injected into the hollow barrel. This device was made using medical syringe (made out of an insulating material cylinder). The gas was fed into the system via flow

meter. The applied voltage to and the discharge current through the discharge chamber were measured using a voltage divider (Homemade), which was connected between the two electrodes, and a current monitor, which can be located upon returning to the ground. The signals from the voltage divider and the current monitor were recorded in a digitizing oscilloscope (Lecroy, USA) with a 200-MHz bandwidth. The high voltage pulses are applied between the needle electrode positioned inside a dielectric cylinder (a simple medical syringe) and a metal ring placed on the exterior of this cylinder. In order to obtain electric discharges at atmospheric pressure, a high voltage pulses (tens of kV) which have limited duration (hundreds of nanoseconds) and are repeated (tens of pulses per second), in addition to an inert gas (argon) is introduced in the cylinder.

The gas flows were in the range 0.5-10 l/min. The discharge takes place between the metallic needle top and a metallic ring fit on the outer surface of the syringe. Under optimal conditions, plasma is emitted as centimeter-long jets, just millimeters in diameter or even smaller. The working gases are supplied by high-pressure cylinders. Gas pressure regulators are used to reduce the pressure of gases to a workable level. Then, gas flow controllers deliver the gases with the desired flow. For voltage amplitudes of 15-18 kV, the plasma jet is very weak. The plasma jet disappears for voltage amplitudes lower than 15 kV. When argon is injected from the gas inlet and high voltage pulses, 26 kV voltages is applied to the electrode, the plasma jet is generated and a plasma plume reaching length of 21 mm is launched through the end of the tube and in the surrounding air. The length of the plasma plume can be adjusted by the gas flow rate and the applied voltage. Three bags from each of sliced chicken were exposed to plasma at 0.5, 1.0 and 1.5 min in Plasma Physics and Nuclear Fusion Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Cairo, Egypt. After the exposure time of plasma, all samples were stored at  $4\pm 1^\circ\text{C}$ .

## 2.2 MICROBIAL ANALYSIS<sup>26</sup>

psychrophilic bacterial count according to (FDA, 2002).

## 2.3 STATISTICAL ANALYSIS<sup>26</sup>

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was  $P \leq 0.05$ .

The experimental data<sup>26</sup> obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations: like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_j x_j + \sum \beta_{jj} x_j^2 + \sum \beta_{ij} x_i x_j$ , where  $y$  is the response,  $x_i$  and  $x_j$  are the uncoded independent variables (factors), and  $\beta_0$ ,  $\beta_i$  &  $\beta_j$ ,  $\beta_{ii}$  &  $\beta_{jj}$  and  $\beta_{ij}$  are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs. In this the Total Psychrophilic bacterial count was the response and the dependent two factors were the Storage time and the cold atmospheric plasma treatment time given to the sliced chicken.

## 3 RESULT AND DISCUSSION

The result of statistical Analysis are shown below:

*Table 1. shows the fit summary the models*

Response 1 Psychrophili Transform: None

\*\*\* WARNING: The Cubic Model and higher are Aliased! \*\*\*

Summary (detailed tables shown below)

Source	Sequential p-value	Lack of Fit p-value	Adjusted R-Squared	Predicted R-Squared	
Linear	0.0087		0.4435	0.1295	
<u>2FI</u>	<u>&lt; 0.0001</u>		<u>0.8418</u>	<u>0.6749</u>	<u>Suggested</u>
Quadratic	0.5490		0.8316	0.5806	
Cubic	0.1802		0.8752	0.1948	Aliased

Table 2. Shows the model sum of square

Sequential Model Sum of Squares [Type I]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	3.714E+008	1	3.714E+008			
Linear vs Mean	4.697E+008	2	2.348E+008	6.98	0.0087	
<u>2FI vs Linear</u>	<u>3.227E+008</u>	<u>1</u>	<u>3.227E+008</u>	<u>33.72</u>	<u>&lt; 0.0001</u>	<u>Suggested</u>
Quadratic vs 2	1.298E+007	2	6.490E+006	0.64	0.5490	
Cubic vs Quad	4.903E+007	3	1.634E+007	2.17	0.1802	Aliased
Residual	5.283E+007	7	7.548E+006			
Total	1.279E+009	16	7.991E+007			

Table 3. Model summary Statistics

Model Summary Statistics

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	5801.32	0.5177	0.4435	0.1295	7.897E+008	
<u>2FI</u>	<u>3093.55</u>	<u>0.8734</u>	<u>0.8418</u>	<u>0.6749</u>	<u>2.949E+008</u>	<u>Suggested</u>
Quadratic	3191.55	0.8877	0.8316	0.5806	3.805E+008	
Cubic	2747.28	0.9418	0.8752	0.1948	7.305E+008	Aliased

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	7.924E+008	3	2.641E+008	27.60	< 0.0001	significant
A-storage pe.	3.727E+008	1	3.727E+008	38.95	< 0.0001	
B-TCAP	7.819E+008	1	7.819E+008	81.70	< 0.0001	
AB	3.227E+008	1	3.227E+008	33.72	< 0.0001	
Residual	1.148E+008	12	9.570E+006			
Cor Total	9.072E+008	15				

The Model F-value of 27.60 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Table 5. ANNOVA Summary

Std. Dev.	3093.55	R-Squared	0.8734
Mean	4818.13	Adj R-Squared	0.8418
C.V. %	64.21	Pred R-Square	0.6749
PRESS	2.949E+008	Adeq Precisor	14.911

The "Pred R-Squared" of 0.6749 is in reasonable agreement with the "Adj R-Squared" of 0.8418; i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 14.911 indicates an adequate signal. This model can be used to navigate the design space.

The developed Fit Suggested required Model in term of Coded Factors:

**Final Equation in Terms of Coded Factors:**

$$\begin{aligned} \text{Psychrophilic bacterial count} = & \\ & +11388.01 \\ & +11566.68 * A \\ & -11813.74 * B \\ & -11977.58 * AB \end{aligned}$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The developed Fit Suggested required Model in term of Actual Factors:

**Final Equation in Terms of Actual Factors:**

$$\begin{aligned} \text{Psychrophilic bacterial count} = & \\ & -506.33363 \\ & +2841.74625 * \text{storage period} \\ & +327.67142 * \text{TCAP} \\ & -1916.41211 * \text{storage period} * \text{TCAP} \end{aligned}$$

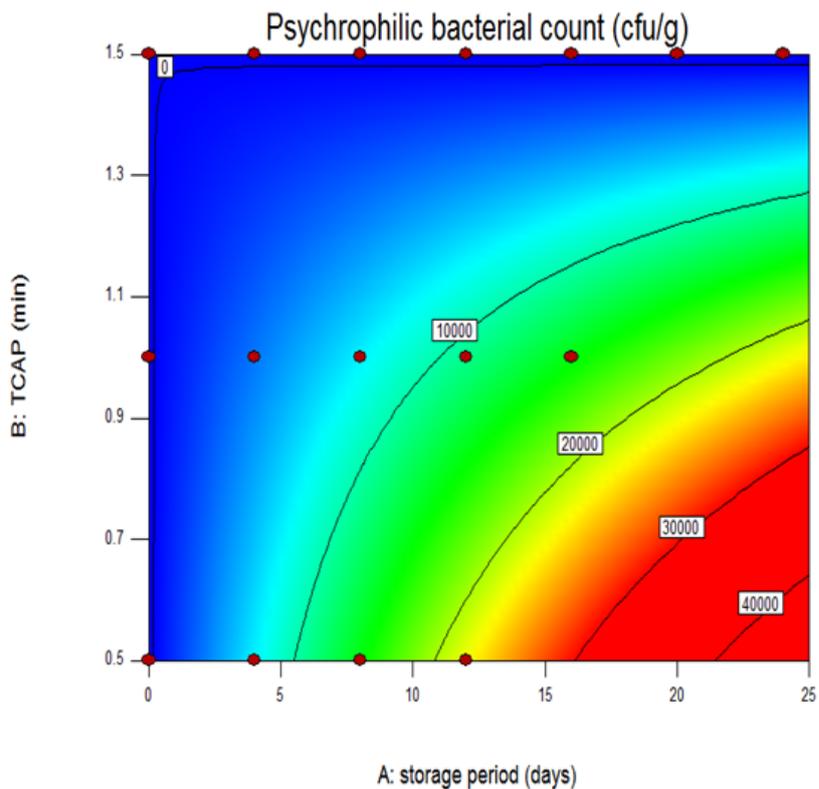


Fig 1. Shows the Contour Graph for the developed Model.

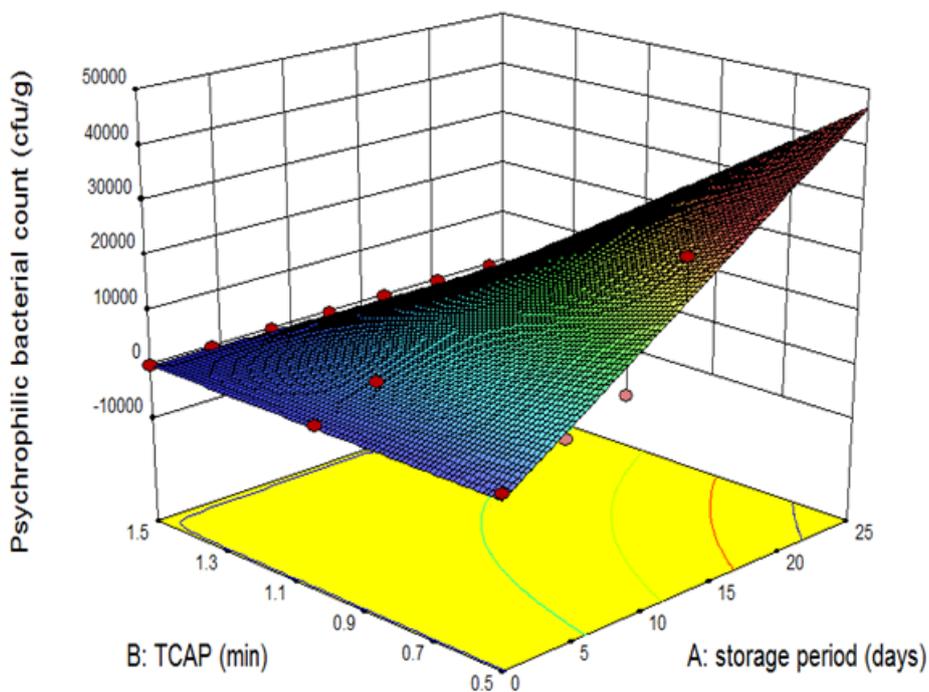


Fig 2. Shows the 3-D Graph Plotted between PBC, TCAP and SP. For the developed model.

## **4 CONCLUSION**

Thus we get a most fitted model for the function of total bacterial count (PBC) with cold atmospheric plasma treatment time (TCAP) and storage period (SP) as the two variants, with  $R^2 = 0.8734$ , F value 27.60 and P value  $<0.0001$ , the suggested model is more significant for the given design data set.

## **ACKNOWLEDGEMENT**

We are appreciative of the SHIATS University for its continuous support in the development of important technologies for the future use. The effort of higher authorities to promote the technologies has been very valuable in the promotion of new technologies. A special thanks goes to the dean and head of department for believing in our dream to develop new technologies. Many people have contributed either directly or indirectly to make this work a reality.

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#### AUTHOR'S BIOGRAPHY

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



## Modeling of Sensory Quality (Appearance) of the Sliced Chicken as a Function of Period of Storage and Gamma-Irradiation Dose Given

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This paper deals with the developing the most suggested model with  $R^2 = 0.9567$  for Sensory (Appearance) Quality as a function of the irradiation dose and the storage period for a sliced chicken meat.

**KEYWORDS:** Irradiation, Radiation, Modeling, Cobalt-60, Radiolysis, Design Expert Software 8.0.

### 1 INTRODUCTION

Poultry carcasses are commonly contaminated with en-teric pathogens such as Salmonella, Campylobacter and *Listeria monocytogenes* (Jacobsreitsma et al., 1994; Murphy et al., 2004); the possibility of cross contamination of poultry carcasses post slaughter is high. Decontamination of poultry carcasses is therefore desirable. Various decontamination technologies have been proposed including the use of various chemical agents such as alkali (Rodriguez et al., 1996), physical methods such as steam treatment (James et al., 2007) and biological control with bacteriophages (Carvalho et al., 2010), but only treat-ment with water supplemented with chlorine or a chlorine-ting agent is used commercially. The effects of such decontaminating treatments are limited (Oyarzabal, 2005; Russell and Axtell, 2005).

The term "radiation chemistry" refers to the chemical reactions that occur as a result of the absorption of ionizing radiation. In the context of food irradiation, the reactants are the chemical constituents of the food and initial radiolysis products that may undergo further chemical reactions. The chemistry involved in the irradiation of foods has been the subject of numerous studies over the years and scientists have compiled a large body of data regarding the effects of ionizing radiation on different foods under various conditions of irradiation. The basic principles are well understood and provide the basis for extrapolation and generalization from data obtained in specific foods irradiated under specific conditions to draw conclusions regarding foods of a similar type irradiated under different, yet related, conditions. The types and amounts of products generated by radiation induced chemical reactions ["radiolysis products"] depend on both the chemical constituents of the food and on the specific conditions of irradiation.

The principles of radiation chemistry also govern the extent of change, if any, in both the nutrient levels and the microbial loads of irradiated foods.

Factors Affecting the Radiation Chemistry of Foods- Apart from the chemical composition of the food itself, the specific conditions of irradiation that are most important in considering the radiation chemistry of a given food include the radiation dose, the physical state of the food (e.g., solid or frozen versus liquid or non-frozen state, dried versus hydrated state), and the ambient atmosphere (e.g., air, reduced oxygen, and vacuum). The temperature at which irradiation is conducted can also be a factor, with more radiation-induced changes occurring with increasing temperature. Temperature is less important, however, than the physical state of the food. The amounts of radiolysis products generated in a particular food are directly proportional to the radiation dose. Therefore, one can extrapolate from data obtained at high radiation doses to draw conclusions regarding the effects at lower doses.

The radiation chemistry of food is strongly influenced by the physical state of the food. If all other conditions, including dose and ambient atmosphere, are the same, the extent of chemical change that occurs in a particular food in the frozen state is less than the change that occurs in the non-frozen state. This is because of the reduced mobility, in the frozen state, of the initial radiolysis products, which will tend to recombine rather than diffuse and react with other food components. Likewise, and for similar reasons, if all other conditions are the same, the extent of chemical change that occurs in the dehydrated state is less than the change that occurs in the fully hydrated state.

The formation of radiolysis products in a given food also is affected by the ambient atmosphere. Irradiation in an atmosphere of high oxygen content generally produces both a greater variety, and greater amounts, of radiolysis products in the food than would be produced in an atmosphere of lower oxygen content. This is because irradiation initiates certain oxidation reactions that occur with greater frequency in foods with high fat content.

With few exceptions, the radiolysis products generated in a particular food are the same or very similar to the products formed in other types of food processing or under common storage conditions. These radiolysis products are also typically formed in very small amounts. Radiation-induced chemical changes, if sufficiently large, however, may cause changes in the organoleptic properties of the food. Because food processors want to avoid undesirable effects on taste, odor, color, or texture, there is an incentive to minimize the extent of these chemical changes in food. Thus, the doses used to achieve a given technical effect (e.g., inhibition of sprouting, reduction in microorganisms) must be selected carefully to both achieve the intended effect and minimize undesirable chemical changes.

Typically, the dose or dose range selected will be the lowest dose practical in achieving the desired effect. Irradiation also is often conducted under reduced oxygen levels or on food held at low temperature or in the frozen state.

In general, during inactivation of microorganisms on surfaces, the rate of inactivation is inversely proportional to the initial cell concentration (Shintani, 2000). Food irradiation is being considered an important tool, in ensuring safety and extending shelf-life of fresh meat and poultry (Yoon, 2003). Thus irradiation can eliminate food-borne pathogenic microorganisms in meat. Furthermore, the use of gamma irradiation as a safety technological treatment in food preservation has now become legally accepted in many countries of the world (Abdel-Daium, 2007).

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the Appearance Quality of the product as a function of the irradiation dose and the storage period of irradiated sliced chicken meat.

## 2 MATERIALS AND METHODS

<sup>26</sup>Sliced chicken were purchased from local market (Benha, Qaliobia governorate, Egypt). All samples were transported to the laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts spore forming bacteria. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

### 2.1 GAMMA IRRADIATION TREATMENTS<sup>26</sup>

Four bags from each of sliced chicken were gamma irradiated at 0, 2, 4, and 6 kGy doses using cobalt-60 gamma chamber (1.367 kGy/h) in Cyclotron Project, Nuclear Research Center Atomic Energy Authority, Inshas, Cairo, Egypt. After irradiation, all samples were stored at 4±1°C.

### 2.2 SENSORY ANALYSIS<sup>26</sup>

### 2.3 STATISTICAL ANALYSIS<sup>26</sup>

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was  $P \leq 0.05$ .

The experimental data<sup>26</sup> obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations: like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_{ij} x_i x_j + \sum \beta_{ij} x_i x_j$ , where  $y$  is the response,  $x_i$  and  $x_j$  are the uncoded independent variables (factors), and  $\beta_0, \beta_i$  &  $\beta_{ij}$ ,  $\beta_{ii}$  &  $\beta_{jj}$  and  $\beta_{ij}$  are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs. In this the product Appearance is the response and the dependent two factors were the Storage time and the gamma-irradiation Dose given to the sliced chicken.

### 3 RESULT AND DISCUSSION

The result of statistical Analysis are shown below:

*Table 1. shows the fit summary the models*

Summary (detailed tables shown below)					
Source	Sequential p-value	Lack of Fit p-value	Adjusted R-Squared	Predicted R-Squared	
Linear	< 0.0001		0.7317	0.6413	
<u>2FI</u>	<u>&lt; 0.0001</u>		<u>0.9486</u>	<u>0.9247</u>	<u>Suggested</u>
Quadratic	0.4511		0.9475	0.9064	
Cubic	0.5106		0.9456	0.7898	
Quartic	0.3559		0.9521	0.2065	Aliased

*Table 2. Shows the model sum of square*

Sequential Model Sum of Squares [Type I]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	1056.04	1	1056.04			
Linear vs Mear	56.23	2	28.12	26.91	< 0.0001	
<u>2FI vs Linear</u>	<u>14.56</u>	<u>1</u>	<u>14.56</u>	<u>72.68</u>	<u>&lt; 0.0001</u>	<u>Suggested</u>
Quadratic vs 2	0.34	2	0.17	0.84	0.4511	
Cubic vs Quad	0.74	4	0.19	0.88	0.5106	
Quartic vs Cub	1.00	4	0.25	1.34	0.3559	Aliased
Residual	1.12	6	0.19			
Total	1130.04	20	56.50			

Table 3. Model summary Statistics

Model Summary Statistics						
Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	1.02	0.7599	0.7317	0.6413	26.54	
2FI	<u>0.45</u>	<u>0.9567</u>	<u>0.9486</u>	<u>0.9247</u>	<u>5.57</u>	<u>Suggested</u>
Quadratic	0.45	0.9613	0.9475	0.9064	6.93	
Cubic	0.46	0.9714	0.9456	0.7898	15.56	
Quartic	0.43	0.9849	0.9521	0.2065	58.71	Aliased

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	70.79	3	23.60	117.79	< 0.0001	significant
A-storage pe.	57.42	1	57.42	286.65	< 0.0001	
B-GID	26.02	1	26.02	129.89	< 0.0001	
AB	14.56	1	14.56	72.68	< 0.0001	
Residual	3.21	16	0.20			
Cor Total	73.99	19				

The Model F-value of 117.79 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Table 5. ANNOVA Summary

Std. Dev.	0.45	R-Squared	0.9567
Mean	7.27	Adj R-Squared	0.9486
C.V. %	6.16	Pred R-Square	0.9247
PRESS	5.57	Adeq Precisor	28.697

The "Pred R-Squared" of 0.9247 is in reasonable agreement with the "Adj R-Squared" of 0.9486; i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 28.697 indicates an adequate signal. This model can be used to navigate the design space.

The developed equation in terms of coded factor:

**Final Equation in Terms of Coded Factors:**

$$\begin{aligned} \text{Appearance} = & \\ & +4.30 \\ & -5.62 * A \\ & +2.96 * B \\ & +3.04 * AB \end{aligned}$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The developed Fit Suggested required Model:

**Final Equation in Terms of Actual Factors:**

$$\begin{aligned} \text{Appearance} = & \\ & +10.00191 \\ & -0.61897 * \text{storage period} \\ & -0.027125 * \text{GID} \\ & +0.072408 * \text{storage period} * \text{GID} \end{aligned}$$

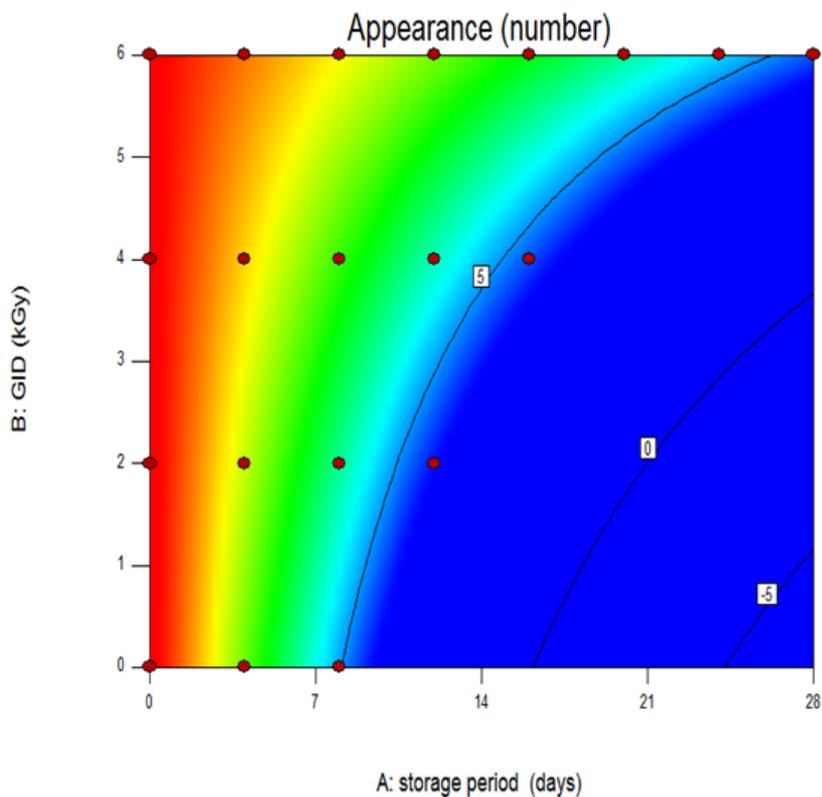


Fig 1. Shows the Contour Graph for the developed Model.

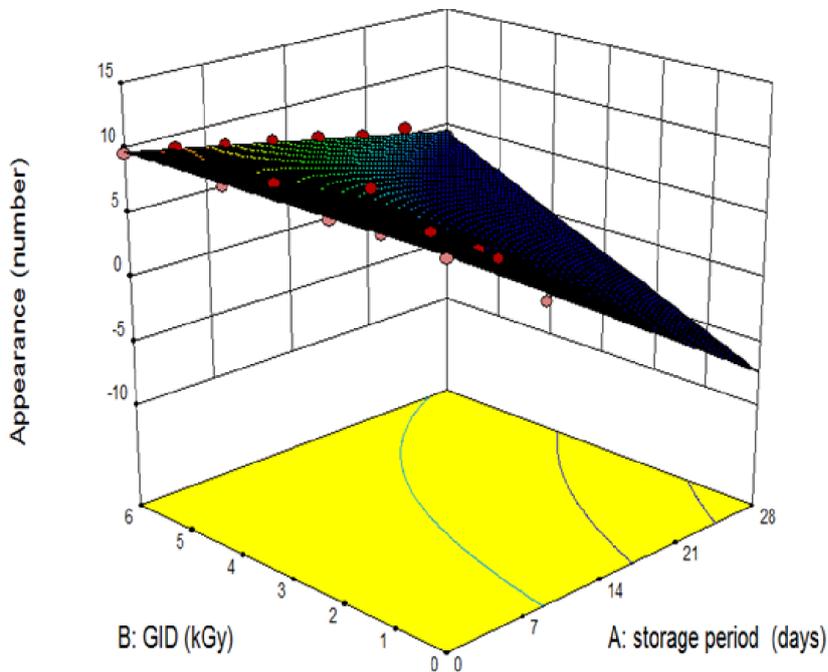


Fig 2. Shows the 3-D Graph Plotted between Appearance, GID and SP. For the developed model.

4 CONCLUSION

Thus we get a most fitted model for Appearance as a function of the gamma Irradiation dose (GID) and storage period (SP) as the two variants, with  $R^2 = 0.9567$ , F value 117.79 and P value  $<0.0001$ , the suggested model is more significant for the given design data set.

#### **ACKNOWLEDGEMENT**

We are appreciative of the SHIATS University for its continuous support in the development of important technologies for the future use. The effort of higher authorities to promote the technologies has been very valuable in the promotion of new technologies. A special thanks goes to the dean and head of department for believing in our dream to develop new technologies. Many people have contributed either directly or indirectly to make this work a reality.

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#### AUTHOR'S BIOGRAPHY

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



## Modeling for Odor of the Sliced Chicken as a Function of Period of Storage and Gamma-Irradiation Dose Given

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This paper deals with the developing the most suggested model with  $R^2 = 0.9456$  for Sensory (Odor) Quality as a function of the irradiation dose and the storage period for a sliced chicken meat.

**KEYWORDS:** Irradiation, Radiation, Modeling, Cobalt-60, Radiolysis, Design Expert Software 8.0.

### 1 INTRODUCTION

Poultry carcasses are commonly contaminated with en-teric pathogens such as Salmonella, Campylobacter and *Listeria monocytogenes* (Jacobsreitsma et al., 1994; Murphy et al., 2004); the possibility of cross contamination of poultry carcasses post slaughter is high. Decontamination of poultry carcasses is therefore desirable. Various decontamination technologies have been proposed including the use of various chemical agents such as alkali (Rodriguez et al., 1996), physical methods such as steam treatment (James et al., 2007) and biological control with bacteriophages (Carvalho et al., 2010), but only treat-ment with water supplemented with chlorine or a chlorine-ting agent is used commercially. The effects of such decontaminating treatments are limited (Oyarzabal, 2005; Russell and Axtell, 2005).

The term "radiation chemistry" refers to the chemical reactions that occur as a result of the absorption of ionizing radiation. In the context of food irradiation, the reactants are the chemical constituents of the food and initial radiolysis products that may undergo further chemical reactions. The chemistry involved in the irradiation of foods has been the subject of numerous studies over the years and scientists have compiled a large body of data regarding the effects of ionizing radiation on different foods under various conditions of irradiation. The basic principles are well understood and provide the basis for extrapolation and generalization from data obtained in specific foods irradiated under specific conditions to draw conclusions regarding foods of a similar type irradiated under different, yet related, conditions. The types and amounts of products generated by radiation induced chemical reactions ["radiolysis products"] depend on both the chemical constituents of the food and on the specific conditions of irradiation.

The principles of radiation chemistry also govern the extent of change, if any, in both the nutrient levels and the microbial loads of irradiated foods.

Factors Affecting the Radiation Chemistry of Foods- Apart from the chemical composition of the food itself, the specific conditions of irradiation that are most important in considering the radiation chemistry of a given food include the radiation dose, the physical state of the food (e.g., solid or frozen versus liquid or non-frozen state, dried versus hydrated state), and the ambient atmosphere (e.g., air, reduced oxygen, and vacuum). The temperature at which irradiation is conducted can also be a factor, with more radiation-induced changes occurring with increasing temperature. Temperature is less important, however, than the physical state of the food. The amounts of radiolysis products generated in a particular food are directly proportional to the radiation dose. Therefore, one can extrapolate from data obtained at high radiation doses to draw conclusions regarding the effects at lower doses.

The radiation chemistry of food is strongly influenced by the physical state of the food. If all other conditions, including dose and ambient atmosphere, are the same, the extent of chemical change that occurs in a particular food in the frozen state is less than the change that occurs in the non-frozen state. This is because of the reduced mobility, in the frozen state, of the initial radiolysis products, which will tend to recombine rather than diffuse and react with other food components. Likewise, and for similar reasons, if all other conditions are the same, the extent of chemical change that occurs in the dehydrated state is less than the change that occurs in the fully hydrated state.

The formation of radiolysis products in a given food also is affected by the ambient atmosphere. Irradiation in an atmosphere of high oxygen content generally produces both a greater variety, and greater amounts, of radiolysis products in the food than would be produced in an atmosphere of lower oxygen content. This is because irradiation initiates certain oxidation reactions that occur with greater frequency in foods with high fat content.

With few exceptions, the radiolysis products generated in a particular food are the same or very similar to the products formed in other types of food processing or under common storage conditions. These radiolysis products are also typically formed in very small amounts. Radiation-induced chemical changes, if sufficiently large, however, may cause changes in the organoleptic properties of the food. Because food processors want to avoid undesirable effects on taste, odor, color, or texture, there is an incentive to minimize the extent of these chemical changes in food. Thus, the doses used to achieve a given technical effect (e.g., inhibition of sprouting, reduction in microorganisms) must be selected carefully to both achieve the intended effect and minimize undesirable chemical changes.

Typically, the dose or dose range selected will be the lowest dose practical in achieving the desired effect. Irradiation also is often conducted under reduced oxygen levels or on food held at low temperature or in the frozen state.

In general, during inactivation of microorganisms on surfaces, the rate of inactivation is inversely proportional to the initial cell concentration (Shintani, 2000). Food irradiation is being considered an important tool, in ensuring safety and extending shelf-life of fresh meat and poultry (Yoon, 2003). Thus irradiation can eliminate food-borne pathogenic microorganisms in meat. Furthermore, the use of gamma irradiation as a safety technological treatment in food preservation has now become legally accepted in many countries of the world (Abdel-Daium, 2007).

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the Sensory Quality (Odor) of the product as a function of the irradiation dose and the storage period of irradiated sliced chicken meat.

## 2 MATERIALS AND METHODS

<sup>26</sup>Sliced chicken were purchased from local market (Benha, Qaliobia governorate, Egypt). All samples were transported to the laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts spore forming bacteria. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

### 2.1 GAMMA IRRADIATION TREATMENTS<sup>26</sup>

Four bags from each of sliced chicken were gamma irradiated at 0, 2, 4, and 6 kGy doses using cobalt-60 gamma chamber (1.367 kGy/h) in Cyclotron Project, Nuclear Research Center Atomic Energy Authority, Inshas, Cairo, Egypt. After irradiation, all samples were stored at 4±1°C.

### 2.2 SENSORY ANALYSIS<sup>26</sup>

### 2.3 STATISTICAL ANALYSIS<sup>26</sup>

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was  $P \leq 0.05$ .

The experimental data<sup>26</sup> obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations: like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_j x_j + \sum \beta_{jj} x_j^2 + \sum \beta_{ij} x_i x_j$ , where  $y$  is the response,  $x_i$  and  $x_j$  are the uncoded independent variables (factors), and  $\beta_0, \beta_i$  &  $\beta_j, \beta_{ii}$  &  $\beta_{jj}$  and  $\beta_{ij}$  are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs. In this the product Odor is the response and the dependent two factors are the Storage time and the gamma-irradiation Dose given to the sliced chicken.

**3 RESULT AND DISCUSSION**

The result of statistical Analysis are shown below:

*Table 1. shows the fit summary the models*

Summary (detailed tables shown below)					
Source	Sequential p-value	Lack of Fit p-value	Adjusted R-Squared	Predicted R-Squared	
Linear	< 0.0001		0.7044	0.6089	
<u>2FI</u>	<u>&lt; 0.0001</u>		<u>0.9354</u>	<u>0.9055</u>	<u>Suggested</u>
Quadratic	0.4872		0.9334	0.8840	
Cubic	0.2013		0.9460	0.8023	
Quartic	0.4212		0.9489	0.3612	Aliased

*Table 2. Shows the model sum of square*

Sequential Model Sum of Squares [Type I]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	1014.60	1	1014.60			
Linear vs Mear	58.97	2	29.48	23.63	< 0.0001	
<u>2FI vs Linear</u>	<u>16.85</u>	<u>1</u>	<u>16.85</u>	<u>61.79</u>	<u>&lt; 0.0001</u>	<u>Suggested</u>
Quadratic vs 2	0.43	2	0.21	0.76	0.4872	
Cubic vs Quad	1.66	4	0.41	1.82	0.2013	
Quartic vs Cub	0.98	4	0.25	1.14	0.4212	Aliased
Residual	1.29	6	0.22			
Total	1094.78	20	54.74			

Table 3. Model summary Statistics

Model Summary Statistics						
Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	1.12	0.7355	0.7044	0.6089	31.35	
<u>2FI</u>	<u>0.52</u>	<u>0.9456</u>	<u>0.9354</u>	<u>0.9055</u>	<u>7.58</u>	<u>Suggested</u>
Quadratic	0.53	0.9509	0.9334	0.8840	9.30	
Cubic	0.48	0.9716	0.9460	0.8023	15.85	
Quartic	0.46	0.9839	0.9489	0.3612	51.22	Aliased

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	75.82	3	25.27	92.69	< 0.0001	significant
A-storage pe.	62.69	1	62.69	229.92	< 0.0001	
B-GID	29.19	1	29.19	107.05	< 0.0001	
AB	16.85	1	16.85	61.79	< 0.0001	
Residual	4.36	16	0.27			
Cor Total	80.18	19				

The Model F-value of 92.69 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Table 5. ANNOVA Summary

Std. Dev.	0.52	R-Squared	0.9456
Mean	7.12	Adj R-Squared	0.9354
C.V. %	7.33	Pred R-Square	0.9055
PRESS	7.58	Adeq Precisiorn	25.963

The "Pred R-Squared" of 0.9055 is in reasonable agreement with the "Adj R-Squared" of 0.9354; i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 25.963 indicates an adequate signal. This model can be used to navigate the design space.

The developed equation in terms of coded factor:

**Final Equation in Terms of Coded Factors:**

$$\begin{aligned} \text{odor} = & \\ & +4.00 \\ & -5.88 * A \\ & +3.13 * B \\ & +3.27 * AB \end{aligned}$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The developed Fit Suggested required Model:

**Final Equation in Terms of Actual Factors:**

$$\begin{aligned} \text{odor} = & \\ & +10.01068 \\ & -0.65342 * \text{storage period} \\ & -0.045569 * \text{GID} \\ & +0.077890 * \text{storage period} * \text{GID} \end{aligned}$$

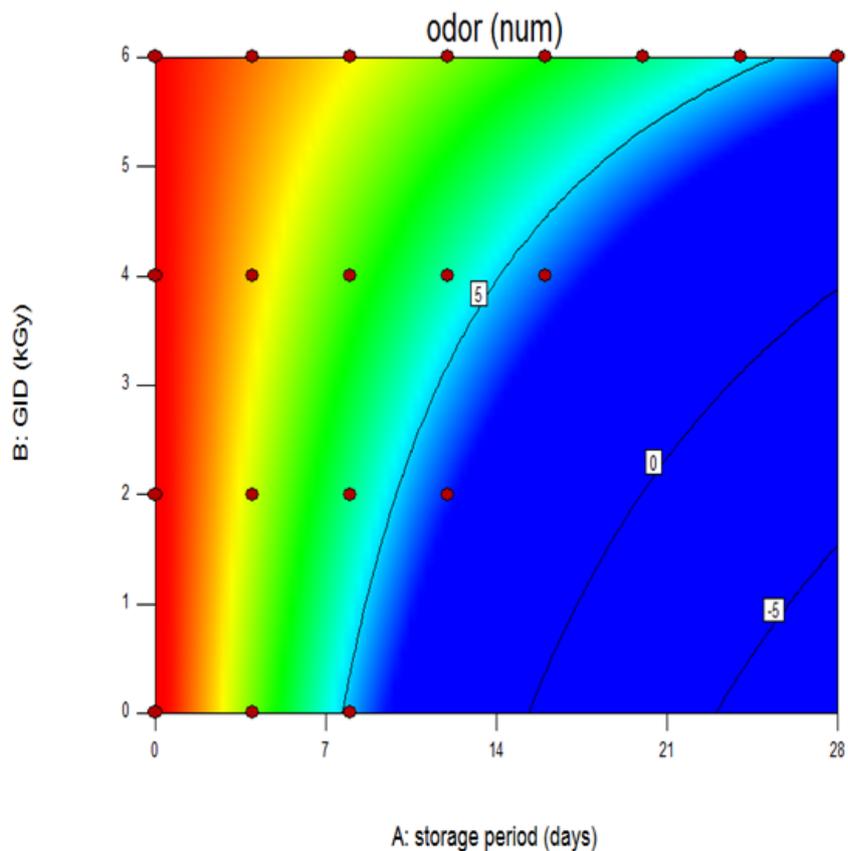


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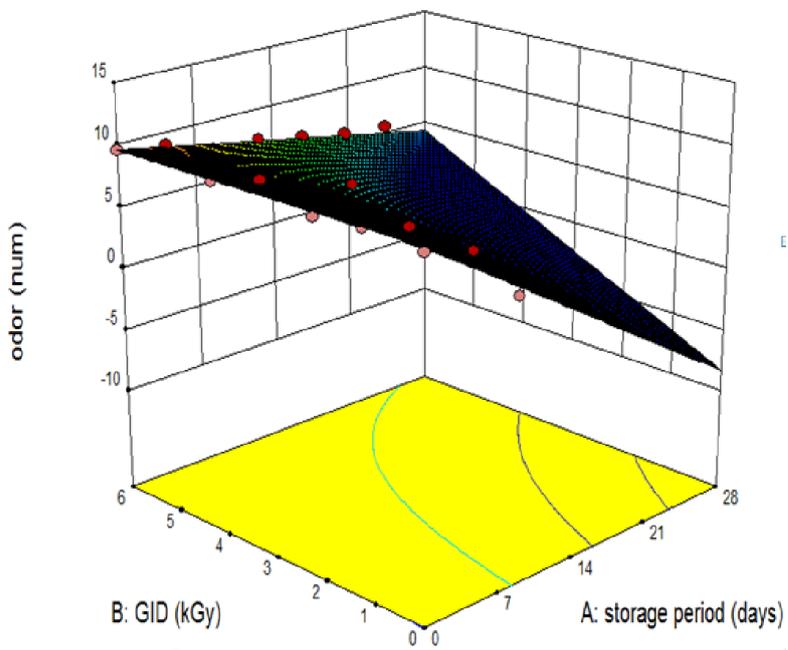


Fig 2. Shows the 3-D Graph Plotted between Odor, GID and SP For the developed model.

## 4 CONCLUSION

Thus we get a most fitted model for Odor of the product as a function of the gamma Irradiation dose (GID) and storage period (SP) as the two variants, with  $R^2 = 0.9456$ , F value 92.69 and P value  $<0.0001$ , the suggested model is more significant for the given design data set.

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#### AUTHOR'S BIOGRAPHY

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



## Modeling of Sensory Quality (Texture) of the Sliced Chicken as a Function of Period of Storage and Gamma-Irradiation Dose Given

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This paper deals with the developing the most suggested model with  $R^2 = 0.9488$  for Sensory (Texture) Quality as a function of the irradiation dose and the storage period for a sliced chicken meat.

**KEYWORDS:** Irradiation, Radiation, Modeling, Cobalt-60, Radiolysis, Design Expert Software 8.0.

### 1 INTRODUCTION

Poultry carcasses are commonly contaminated with en-teric pathogens such as Salmonella, Campylobacter and *Listeria monocytogenes* (Jacobsreitsma et al., 1994; Murphy et al., 2004); the possibility of cross contamination of poultry carcasses post slaughter is high. Decontamination of poultry carcasses is therefore desirable. Various decontamination technologies have been proposed including the use of various chemical agents such as alkali (Rodriguez et al., 1996), physical methods such as steam treatment (James et al., 2007) and biological control with bacteriophages (Carvalho et al., 2010), but only treat-ment with water supplemented with chlorine or a chlorine-ting agent is used commercially. The effects of such decontaminating treatments are limited (Oyarzabal, 2005; Russell and Axtell, 2005).

The term "radiation chemistry" refers to the chemical reactions that occur as a result of the absorption of ionizing radiation. In the context of food irradiation, the reactants are the chemical constituents of the food and initial radiolysis products that may undergo further chemical reactions. The chemistry involved in the irradiation of foods has been the subject of numerous studies over the years and scientists have compiled a large body of data regarding the effects of ionizing radiation on different foods under various conditions of irradiation. The basic principles are well understood and provide the basis for extrapolation and generalization from data obtained in specific foods irradiated under specific conditions to draw conclusions regarding foods of a similar type irradiated under different, yet related, conditions. The types and amounts of products generated by radiation induced chemical reactions ["radiolysis products"] depend on both the chemical constituents of the food and on the specific conditions of irradiation.

The principles of radiation chemistry also govern the extent of change, if any, in both the nutrient levels and the microbial loads of irradiated foods.

Factors Affecting the Radiation Chemistry of Foods- Apart from the chemical composition of the food itself, the specific conditions of irradiation that are most important in considering the radiation chemistry of a given food include the radiation dose, the physical state of the food (e.g., solid or frozen versus liquid or non-frozen state, dried versus hydrated state), and the ambient atmosphere (e.g., air, reduced oxygen, and vacuum). The temperature at which irradiation is conducted can also be a factor, with more radiation-induced changes occurring with increasing temperature. Temperature is less important, however, than the physical state of the food. The amounts of radiolysis products generated in a particular food are directly proportional to the radiation dose. Therefore, one can extrapolate from data obtained at high radiation doses to draw conclusions regarding the effects at lower doses.

The radiation chemistry of food is strongly influenced by the physical state of the food. If all other conditions, including dose and ambient atmosphere, are the same, the extent of chemical change that occurs in a particular food in the frozen state is less than the change that occurs in the non-frozen state. This is because of the reduced mobility, in the frozen state, of the initial radiolysis products, which will tend to recombine rather than diffuse and react with other food components. Likewise, and for similar reasons, if all other conditions are the same, the extent of chemical change that occurs in the dehydrated state is less than the change that occurs in the fully hydrated state.

The formation of radiolysis products in a given food also is affected by the ambient atmosphere. Irradiation in an atmosphere of high oxygen content generally produces both a greater variety, and greater amounts, of radiolysis products in the food than would be produced in an atmosphere of lower oxygen content. This is because irradiation initiates certain oxidation reactions that occur with greater frequency in foods with high fat content.

With few exceptions, the radiolysis products generated in a particular food are the same or very similar to the products formed in other types of food processing or under common storage conditions. These radiolysis products are also typically formed in very small amounts. Radiation-induced chemical changes, if sufficiently large, however, may cause changes in the organoleptic properties of the food. Because food processors want to avoid undesirable effects on taste, odor, color, or texture, there is an incentive to minimize the extent of these chemical changes in food. Thus, the doses used to achieve a given technical effect (e.g., inhibition of sprouting, reduction in microorganisms) must be selected carefully to both achieve the intended effect and minimize undesirable chemical changes.

Typically, the dose or dose range selected will be the lowest dose practical in achieving the desired effect. Irradiation also is often conducted under reduced oxygen levels or on food held at low temperature or in the frozen state.

In general, during inactivation of microorganisms on surfaces, the rate of inactivation is inversely proportional to the initial cell concentration (Shintani, 2000). Food irradiation is being considered an important tool, in ensuring safety and extending shelf-life of fresh meat and poultry (Yoon, 2003). Thus irradiation can eliminate food-borne pathogenic microorganisms in meat. Furthermore, the use of gamma irradiation as a safety technological treatment in food preservation has now become legally accepted in many countries of the world (Abdel-Daium, 2007).

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the Textural Quality of the product as a function of the irradiation dose and the storage period of irradiated sliced chicken meat.

## 2 MATERIALS AND METHODS

<sup>26</sup>Sliced chicken were purchased from local market (Benha, Qalibia governorate, Egypt). All samples were transported to the laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts spore forming bacteria. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

### 2.1 GAMMA IRRADIATION TREATMENTS<sup>26</sup>

Four bags from each of sliced chicken were gamma irradiated at 0, 2, 4, and 6 kGy doses using cobalt-60 gamma chamber (1.367 kGy/h) in Cyclotron Project, Nuclear Research Center Atomic Energy Authority, Inshas, Cairo, Egypt. After irradiation, all samples were stored at 4±1°C.

### 2.2 SENSORY (TEXTURE) ANALYSIS<sup>26</sup>

### 2.3 STATISTICAL ANALYSIS<sup>26</sup>

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was  $P \leq 0.05$ .

The experimental data<sup>26</sup> obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations:

like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_j x_j + \sum \beta_{jj} x_j^2 + \sum \beta_{ij} x_i x_j$ , where  $y$  is the response,  $x_i$  and  $x_j$  are the uncoded independent variables (factors), and  $\beta_0, \beta_i$  &  $\beta_j, \beta_{ii}$  &  $\beta_{jj}$  and  $\beta_{ij}$  are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs. In this the product Texture is the response and the dependent two factors were the Storage time and the gamma-irradiation Dose given to the sliced chicken.

### 3 RESULT AND DISCUSSION

The result of statistical Analysis are shown below:

*Table 1. shows the fit summary the models*

Summary (detailed tables shown below)					
	Sequential	Lack of Fit	Adjusted	Predicted	
Source	p-value	p-value	R-Squared	R-Squared	
Linear	< 0.0001		0.6840	0.5800	
<u>2FI</u>	<u>&lt; 0.0001</u>		<u>0.9392</u>	<u>0.9102</u>	<u>Suggested</u>
Quadratic	0.6682		0.9344	0.8770	
Cubic	0.4155		0.9359	0.7259	
Quartic	0.2782		0.9491	0.0865	Aliased

*Table 2. Shows the model sum of square*

Sequential Model Sum of Squares [Type I]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	838.38	1	838.38			
Linear vs Mean	55.28	2	27.64	21.57	< 0.0001	
<u>2FI vs Linear</u>	<u>17.84</u>	<u>1</u>	<u>17.84</u>	<u>72.30</u>	<u>&lt; 0.0001</u>	<u>Suggested</u>
Quadratic vs 2	0.22	2	0.11	0.41	0.6682	
Cubic vs Quad	1.13	4	0.28	1.08	0.4155	
Quartic vs Cub	1.36	4	0.34	1.65	0.2782	Aliased
Residual	1.24	6	0.21			
Total	915.45	20	45.77			

Table 3. Model summary Statistics

Model Summary Statistics						
Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	1.13	0.7173	0.6840	0.5800	32.37	
<b>2FI</b>	<b>0.50</b>	<b>0.9488</b>	<b>0.9392</b>	<b>0.9102</b>	<b>6.92</b>	<b>Suggested</b>
Quadratic	0.52	0.9516	0.9344	0.8770	9.48	
Cubic	0.51	0.9663	0.9359	0.7259	21.13	
Quartic	0.45	0.9839	0.9491	0.0865	70.40	Aliased

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	73.12	3	24.37	98.78	< 0.0001	significant
A-storage pe.	61.84	1	61.84	250.65	< 0.0001	
B-GID	29.30	1	29.30	118.76	< 0.0001	
AB	17.84	1	17.84	72.30	< 0.0001	
Residual	3.95	16	0.25			
Cor Total	77.07	19				

The Model F-value of 98.78 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Table 5. ANNOVA Summary

Std. Dev.	0.50	R-Squared	0.9488
Mean	6.47	Adj R-Squared	0.9392
C.V. %	7.67	Pred R-Square	0.9102
PRESS	6.92	Adeq Precisor	27.528

The "Pred R-Squared" of 0.9102 is in reasonable agreement with the "Adj R-Squared" of 0.9392; i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 27.528 indicates an adequate signal. This model can be used to navigate the design space.

The developed equation in terms of coded factor:

**Final Equation in Terms of Coded Factors:**

$$\begin{aligned}\text{Texture} = & \\ & +3.35 \\ & -5.84 * A \\ & +3.14 * B \\ & +3.37 * AB\end{aligned}$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The developed Fit Suggested required Model:

**Final Equation in Terms of Actual Factors:**

$$\begin{aligned}\text{Texture} = & \\ & +9.41281 \\ & -0.65737 * \text{storage period} \\ & -0.075196 * \text{GID} \\ & +0.080152 * \text{storage period} * \text{GID}\end{aligned}$$

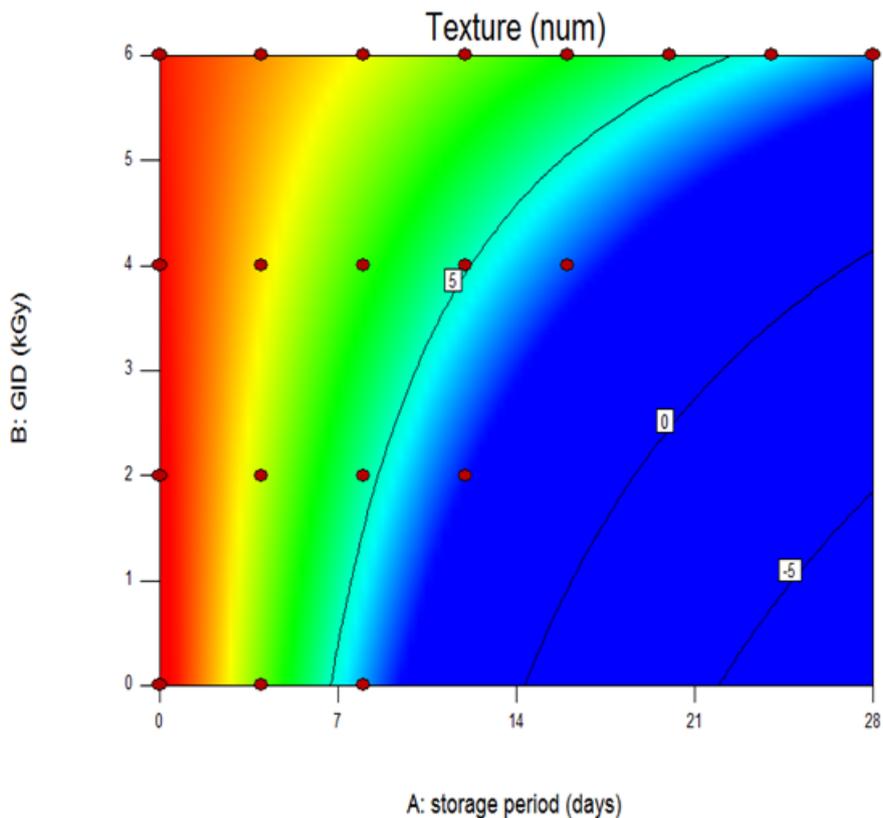


Fig 1. Shows the Contour Graph for the developed Model.

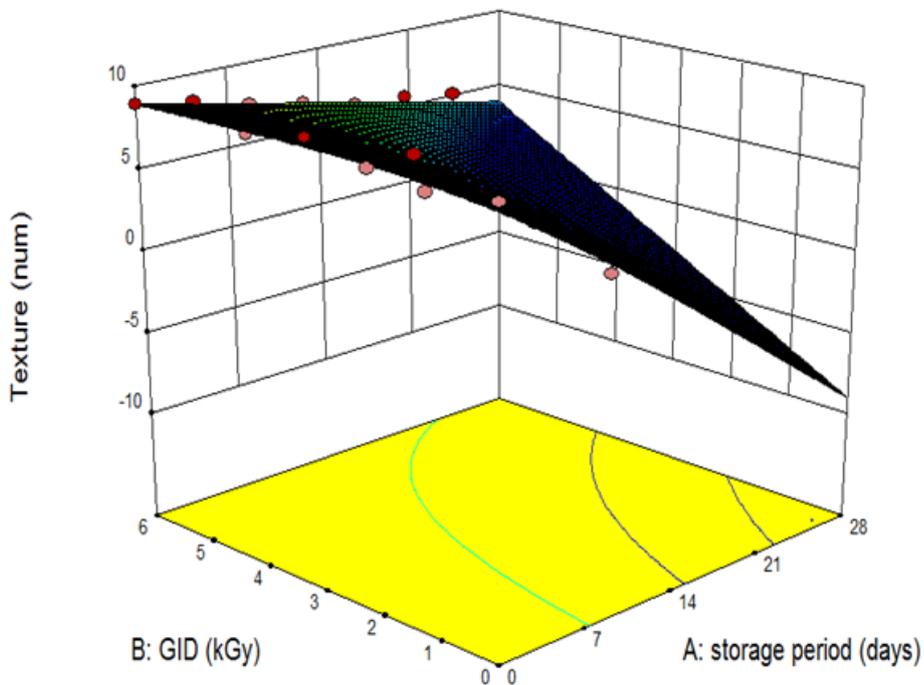


Fig 2. Shows the 3-D Graph Plotted between Texture, GID and SP. For the developed model.

4 CONCLUSION

Thus we get a most fitted model for Texture as a function of the gamma Irradiation dose (GID) and storage period (SP) as the two variants, with  $R^2 = 0.9488$ , F value 98.78 and P value  $<0.0001$ , the suggested model is more significant for the given design data set.

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#### AUTHOR'S BIOGRAPHY

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



## Modeling of Quality (Appearance) attribute of the Sliced Chicken as a Function of Period of Storage and Time of Cold Atmospheric Plasma Given

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This paper deals with the developing the most suggested model with  $R^2 = 0.9687$  for Quality (Appearance) as a function of the cold plasma treatment time and the storage period for a sliced chicken meat.

**KEYWORDS:** Cold Atmospheric Plasma, Molecular oxygen, Modeling, Ionized gas, Design Expert Software 8.0.

### 1 INTRODUCTION

Poultry carcasses are commonly contaminated with en-teric pathogens such as Salmonella, Campylobacter and *Listeria monocytogenes* (Jacobsreitsma et al., 1994; Murphy et al., 2004); the possibility of cross contamination of poultry carcasses post slaughter is high. Decontamination of poultry carcasses is therefore desirable. Various decontamination technologies have been proposed including the use of various chemical agents such as alkali (Rodriguez et al., 1996), physical methods such as steam treatment (James et al., 2007) and biological control with bacteriophages (Carvalho et al., 2010), but only treat-ment with water supplemented with chlorine or a chlorine-ting agent is used commercially. The effects of such decontaminating treatments are limited (Oyarzabal, 2005; Russell and Axtell, 2005).

#### 1.1 PLASMA SCIENCE

##### 1.1.1 PLASMA- DEFINITION, PHYSICS AND CHEMISTRY

In 1922, the American scientist Irving Langmuir proposed that the electrons, ions and neutrals in an ionized gas could be considered as corpuscular material entrained in some kind of fluid medium and termed this entraining medium "*plasma*", similar to the plasma, introduced by the Czech physiologist Jan Evangelista Purkinje to denote the clear fluid which remains after removal of all the corpuscular material in blood. However, it emerged that there was no "fluid medium" entraining the electrons, ions, and neutrals in an ionized gas (Bellan 2006), nevertheless the name prevailed. The term "*plasma*" refers to a partially or wholly ionized gas composed essentially of photons, ions and free electrons as well as atoms in their fundamental or excited states possessing a net neutral charge. The plasma possesses a net neutral charge because the number of positive charge carriers is equal to the number of negative ones (Kudra and Mujumdar 2009). Electrons and photons are usually designated as "light" species in contrast to the rest of the constituents designated as "heavy" species. Due to its unique properties plasma is often referred to as the fourth state of matter according to a scheme expressing an increase in the energy level from solid to liquid to gas and ultimately to plasma.

##### 1.1.2 TYPES OF PLASMA

Two classes of plasma, namely thermal and NTP can be distinguished on the basis of conditions in which they are generated. This classification of plasma is based on the relative energetic levels of electrons and heavy species of the plasma. NTP (near ambient temperatures of 30-60oC) is obtained at atmospheric or reduced pressures (vacuum) and requires less

power. NTPs are characterised by an electron temperature much above that of the gas (macroscopic temperature) and consequently do not present a local thermodynamic equilibrium. NTP can be generated by an electric discharge in a gas at lower pressure or using microwaves. Typical illustrations for plasma generation at atmospheric pressure include the corona discharge, Dielectric barrier discharges (DBD), Radio-frequency plasmas (RFP) and the gliding arc discharge. In contrast, thermal plasmas are generated at higher pressures, require high power, and an almost thermal equilibrium exists between the electrons and the heavy species. Plasma generation at atmospheric pressure is of interest, both technically and industrially for the food industries because this does not require extreme conditions.

## 1.2 ACTION OF PLASMA ON MICROORGANISMS

### 1.2.1 ACTION ON CELL COMPONENTS AND FUNCTIONS

The use of sterilizing properties of plasma was first introduced towards the end of 60s, patented in 1968 (Menashi 1968) and first works with plasma made from oxygen were proposed in 1989. Thereafter, considerable research has been performed on the mechanism of microbial inactivation by plasma agents. The plasma agents contribute to the lethal action by interacting with the biological material. Nelson and Berger (1989) have shown that O<sub>2</sub> plasma could be a very efficient biocidal against bacteria. Plasma treatment can effectively inactivate a wide range of micro-organisms including spores (Kelly-Wintenberg et al. 1999; Feichtinger et al. 2003; Lee et al. 2006) and viruses (Terrier et al. 2009). Effect of plasma can be quite selective, meaning tuneable between damage to pathogenic organisms without damage to the host, or activation of different pathways in different organisms (Dobrynin et al. 2009). Low-pressure oxygen plasma has been shown to degrade lipids, proteins and DNA of cells (Mogul et al. 2003). The reactive species in plasma have been widely associated to the direct oxidative effects on the outer surface of microbial cells. As an example, commonly used oxygen and nitrogen gas plasma are excellent sources of reactive oxygen-based and nitrogen-based species, such as O•, O<sup>2</sup>, O<sup>3</sup>, OH•, NO•, NO<sub>2</sub> etc.

Atomic oxygen is potentially a very effective sterilizing agent, with a chemical rate constant for oxidation at room temperature of about 106 times that of molecular oxygen (Critzler et al. 2007). These act on the unsaturated fatty acids of the lipid bilayer of the cell membrane, thereby impeding the transport of bio-molecules across it. The double bonds of unsaturated lipids are particularly vulnerable to ozone attack (Guzel-Seydim et al. 2004). Membrane lipids are assumed to be more significantly affected by the reactive oxygen species (ROS) due to their location along the surface of bacterial cell, which allows them to be bombarded by these strong oxidizing agents (Montie et al. 2002). The proteins of the cells and the spores are equally vulnerable to the action of these species, causing denaturation and cell leakage. Oxidation of amino acids and nucleic acids may also cause changes that result in microbial death or injury (Critzler et al. 2007). Micro-organisms in plasma are exposed to an intense bombardment by the radicals most likely provoking surface lesions that the living cell cannot repair sufficiently faster. This may partially explain the observations wherein cells are in many cases destroyed very quickly. This process is termed "etching" (Pelletier 1992). The cell wall rupture has been additionally attributed by Laroussi et al., (2003) and Mendis et al., (2002) to electrostatic forces due to accumulation of charges at the outer surface of cell membranes. The morphological changes in *E. coli* cells treated with atmospheric plasma at 75W for 2 min as observed under an electron microscope by (Hong et al. 2009), clearly revealed that the treated cells had severe cytoplasmic deformations and leakage of bacterial chromosome. These observations demonstrate the loss of viability of bacterial cells after plasma treatment. An analogy between plasma and pulsed electric field has also been drawn to explain the action of plasma on the membranes (Pothakamury et al. 1995; Spilimbergo et al. 2003). It is well established that electroporation of membranes is induced by pulsed electric fields and it appears that plasma acts on similar lines inducing perforations in the membranes of micro-organisms (Sale and Hamilton 1967; Pothakamury et al. 1995; Wouters and Smelt 1997). In addition to generating pores, humid air plasma additionally provokes a marked acidification of the medium (Moreau et al. 2005; Moreau et al. 2007).

### 1.2.2 ROLE OF UV PHOTONS AND CHARGED PARTICLES

The production of UV photons of different wavelengths has been proposed to be involved in dimerizing the thymine bases of DNA including that of spores (Munakata et al. 1991). The role of UV photons in bacterial death when they are submitted to a plasma treatment was reviewed in detail by (Boudam et al. 2006). Recently, by exclusion of reactive particles and spectral fractions of UV radiation from access to the spores Roth et al., (2010) revealed that UV-C radiation is the most effective inactivation agent in the plasma. Ultraviolet (UV) photons play a less important role in atmospheric pressure glow discharge (APGD) because they are easily absorbed by gas atoms and molecules at atmospheric pressure (Vleugels et al. 2005). The role of the charged particles in the bacterial inactivation process was recently investigated by Lu *et al.* (2009). Their work revealed that the charged particles play a minor role in the inactivation process when He/N<sub>2</sub> (3%) is used as working gas than when He/O<sub>2</sub> (3%) is used. Also, they concluded that heat and UV play no or minor roles in the inactivation

process. Similar results were earlier obtained by (Perni et al. 2007) who interplayed bacterial inactivation kinetics with optical emission spectroscopy, and identified oxygen atoms as major contributor in plasma inactivation with minor contributions from UV photons, OH radicals, singlet oxygen metastables and nitric oxide. Thus, a contradiction over the role of UV photons in plasma exists and future studies must be directed to get a clear picture.

### **1.2.3 EFFECT OF PROCESS PARAMETERS**

The concentrations in which the plasma agents occur in plasma depend greatly on the device set-up (reactor geometry), operating conditions (gas pressure, type, flow, frequency and power of plasma excitation) and gas composition which affect their efficacy in a process when employed. To cite an example, the destructive efficiency of various gas plasma sources and temperatures on *Bacillus spp.* spores were compared by (Hury et al. 1998). This group demonstrated that oxygen-based plasma is more efficient than pure argon plasma. Another deciding criterion is whether the substrate to be sterilized is in direct contact with the plasma (*Direct Exposure*) or located remote from it (*Remote Exposure*) (Moisan et al. 2001; Laroussi 2005; Boudam et al. 2006). If exposed remotely, the quantum of heat transmitted to a sample is reduced, the charged particles do not play a role since they recombine before reaching the sample, and many of the short-lived neutral reactive species also do not reach the sample. Since, the components of the plasma are reactive and self-quenching, with a relatively short half-life, decreased time of flight would be expected to be one of the major factors in antimicrobial efficacy in this case (Niemira and Sites 2008). By varying the process parameters involved in plasma generation, a multitude of mechanisms can be actuated which may act individually or synergistically.

Nevertheless, the details of interaction of the different plasma agents with the different components of bacterial cells or spores are currently very limited. The interactions which occur between plasma agents and biological materials, ultimately leading to sterilization are still under investigation.

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the Appearance of CPT sliced chicken as a function of the cold plasma treatment time and the storage period of treated sliced chicken meat.

## **2 MATERIALS AND METHODS**

<sup>26</sup>Sliced chicken were purchased from local market (Benha, Qaliobia governorate, Egypt). All samples were transported to our laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts for counts of total bacteria, psychrophilic bacteria, spore forming bacteria, total molds and yeasts. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

### **2.1 PLASMA TREATMENTS CHARACTER OF EXPOSURE MACHINE**

The plasma generator consisted of a negative dc source, a Blumlein-type pulse-forming network (E-PFN), and a dynamic spark gap switch. A triggered spark gap switch was used as a closing switch of E-PFN. E-PFN had four stages of LC ladder, which were composed of 5 nF of capacitor and 3 μH of inductor. The characteristic impedance ( $2\sqrt{L/C}$ ) and the pulse width ( $2\sqrt{LC}$ ) of E-PFN, calculated from capacitance (C) and inductance (L) of the LC ladder, and number (N) of LC ladder stages were approximately 49 Ω and 1.0 μs, respectively.

A charging resistance value of 50 kΩ was chosen in the present case which corresponds to a charging RC time constant of 1 ms, which is 40 times faster compared to the repetition rate of the pulse. A schematic of the pulsed atmospheric-pressure plasma jet (PAPPJ) device for generating high voltage pulsed, cold atmospheric plasma jets is shown in Figure 1. The high voltage (HV) wire electrode, which is made of a copper wire, is inserted into a hollow barrel of a syringe. The distance between the tip of the HV electrode and the nozzle is 0.5 cm. When HV pulsed, DC voltage (amplitudes up to 25 kV, repetition rate up to 25 Hz), was applied to the HV electrode and helium gas was injected into the hollow barrel. This device was made using medical syringe (made out of an insulating material cylinder). The gas was fed into the system via flow

meter. The applied voltage to and the discharge current through the discharge chamber were measured using a voltage divider (Homemade), which was connected between the two electrodes, and a current monitor, which can be located upon returning to the ground. The signals from the voltage divider and the current monitor were recorded in a digitizing oscilloscope (Lecroy, USA) with a 200-MHz bandwidth. The high voltage pulses are applied between the needle electrode positioned inside a dielectric cylinder (a simple medical syringe) and a metal ring placed on the exterior of this cylinder. In order to obtain electric discharges at atmospheric pressure, a high voltage pulses (tens of kV) which have limited duration (hundreds of nanoseconds) and are repeated (tens of pulses per second), in addition to an inert gas (argon) is introduced in the cylinder.

The gas flows were in the range 0.5-10 l/min. The discharge takes place between the metallic needle top and a metallic ring fit on the outer surface of the syringe. Under optimal conditions, plasma is emitted as centimeter-long jets, just millimeters in diameter or even smaller. The working gases are supplied by high-pressure cylinders. Gas pressure regulators are used to reduce the pressure of gases to a workable level. Then, gas flow controllers deliver the gases with the desired flow. For voltage amplitudes of 15-18 kV, the plasma jet is very weak. The plasma jet disappears for voltage amplitudes lower than 15 kV. When argon is injected from the gas inlet and high voltage pulses, 26 kV voltages is applied to the electrode, the plasma jet is generated and a plasma plume reaching length of 21 mm is launched through the end of the tube and in the surrounding air. The length of the plasma plume can be adjusted by the gas flow rate and the applied voltage. Three bags from each of sliced chicken were exposed to plasma at 0.5, 1.0 and 1.5 min in Plasma Physics and Nuclear Fusion Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Cairo, Egypt. After the exposure time of plasma, all samples were stored at  $4\pm 1^\circ\text{C}$ .

## 2.2 SENSORY ANALYSIS<sup>26</sup>

## 2.3 STATISTICAL ANALYSIS<sup>26</sup>

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was  $P \leq 0.05$ .

The experimental data<sup>26</sup> obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations: like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_j x_j + \sum \beta_{jj} x_j^2 + \sum \beta_{ij} x_i x_j$ , where  $y$  is the response,  $x_i$  and  $x_j$  are the uncoded independent variables (factors), and  $\beta_0$ ,  $\beta_i$  &  $\beta_j$ ,  $\beta_{ii}$  &  $\beta_{jj}$  and  $\beta_{ij}$  are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs. In this the Sensory Attribute (Appearance) was the response and the dependent two factors were the Storage time and the cold atmospheric plasma treatment time given to the sliced chicken.

## 3 RESULT AND DISCUSSION

The result of statistical Analysis are shown below:

*Table 1. shows the fit summary the models*

Summary (detailed tables shown below)

	Sequential	Lack of Fit	Adjusted	Predicted	
Source	p-value	p-value	R-Squared	R-Squared	
Linear	< 0.0001		0.8294	0.7658	
2FI	0.0013		0.9246	0.8903	
<u>Quadratic</u>	<u>0.0379</u>		<u>0.9530</u>	<u>0.9256</u>	<u>Suggested</u>
Cubic	0.2173		0.9630	0.8110	Aliased

Table 2. Shows the model sum of square

Sequential Model Sum of Squares [Type I]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	843.18	1	843.18			
Linear vs Mean	51.77	2	25.89	37.47	< 0.0001	
2FI vs Linear	5.32	1	5.32	17.42	0.0013	
<u>Quadratic vs 2</u>	<u>1.76</u>	<u>2</u>	<u>0.88</u>	<u>4.62</u>	<u>0.0379</u>	<u>Suggested</u>
Cubic vs Quad	0.86	3	0.29	1.90	0.2173	Aliased
Residual	1.05	7	0.15			
Total	903.93	16	56.50			

Table 3. Model summary Statistics

Model Summary Statistics

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	0.83	0.8522	0.8294	0.7658	14.23	
2FI	0.55	0.9397	0.9246	0.8903	6.66	
<u>Quadratic</u>	<u>0.44</u>	<u>0.9687</u>	<u>0.9530</u>	<u>0.9256</u>	<u>4.52</u>	<u>Suggested</u>
Cubic	0.39	0.9827	0.9630	0.8110	11.48	Aliased

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

Response 1 Appearance

ANOVA for Response Surface Quadratic model

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	58.85	5	11.77	61.82	< 0.0001	significant
A-storage pe.	38.33	1	38.33	201.31	< 0.0001	
B-TCAP	15.21	1	15.21	79.91	< 0.0001	
AB	6.48	1	6.48	34.06	0.0002	
A <sup>2</sup>	1.72	1	1.72	9.06	0.0131	
B <sup>2</sup>	0.031	1	0.031	0.16	0.6972	
Residual	1.90	10	0.19			
Cor Total	60.75	15				

The Model F-value of 61.82 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Table 5. ANNOVA Summary

Std. Dev.	0.44	R-Squared	0.9687
Mean	7.26	Adj R-Squared	0.9530
C.V. %	6.01	Pred R-Square	0.9256
PRESS	4.52	Adeq Precisor	21.081

The "Pred R-Squared" of 0.9256 is in reasonable agreement with the "Adj R-Squared" of 0.9530; i.e. the difference is less than 0.2.

"Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 21.081 indicates an adequate signal. This model can be used to navigate the design space.

The developed Fit Suggested required Model in term of Coded Factors:

**Final Equation in Terms of Coded Factors:**

$$\begin{aligned} \text{Appearance} = & \\ & +5.95 \\ & -4.72 * A \\ & +1.94 * B \\ & +2.08 * AB \\ & -1.16 * A^2 \\ & +0.099 * B^2 \end{aligned}$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The developed Fit Suggested required Model in term of Actual Factors:

**Final Equation in Terms of Actual Factors:**

$$\begin{aligned} \text{Appearance} = & \\ & +10.16958 \\ & -0.54575 * \text{storage period} \\ & -1.06124 * \text{TCAP} \\ & +0.34621 * \text{storage period} * \text{TCAP} \\ & -8.06466\text{E-}003 * \text{storage period}^2 \\ & +0.39420 * \text{TCAP}^2 \end{aligned}$$

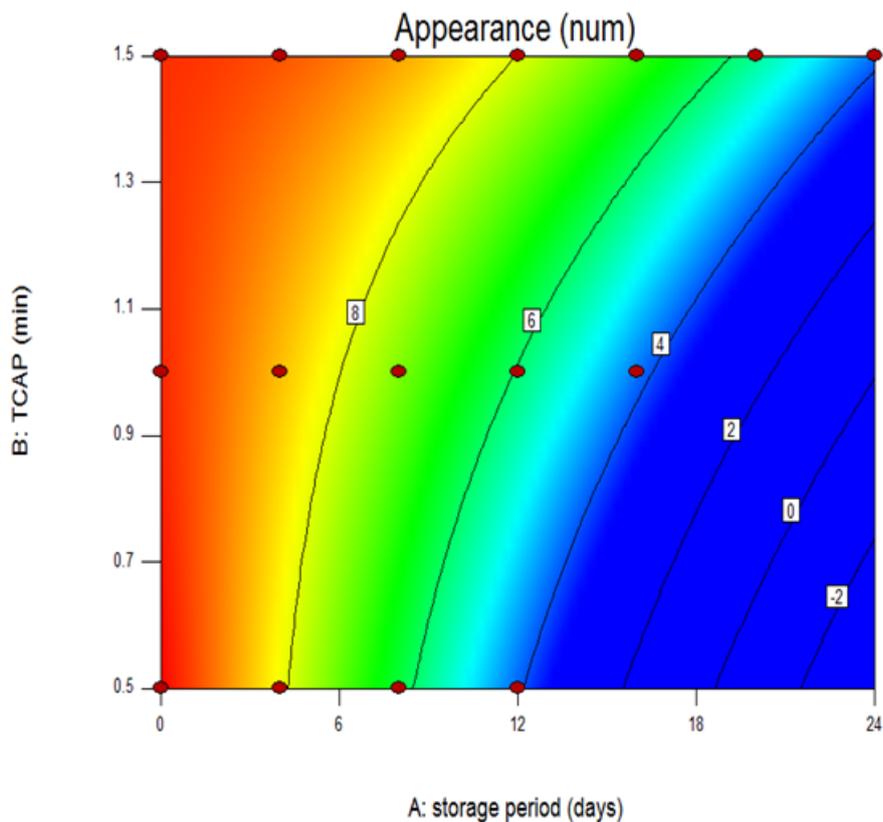


Fig 1. Shows the Contour Graph for the developed Model.

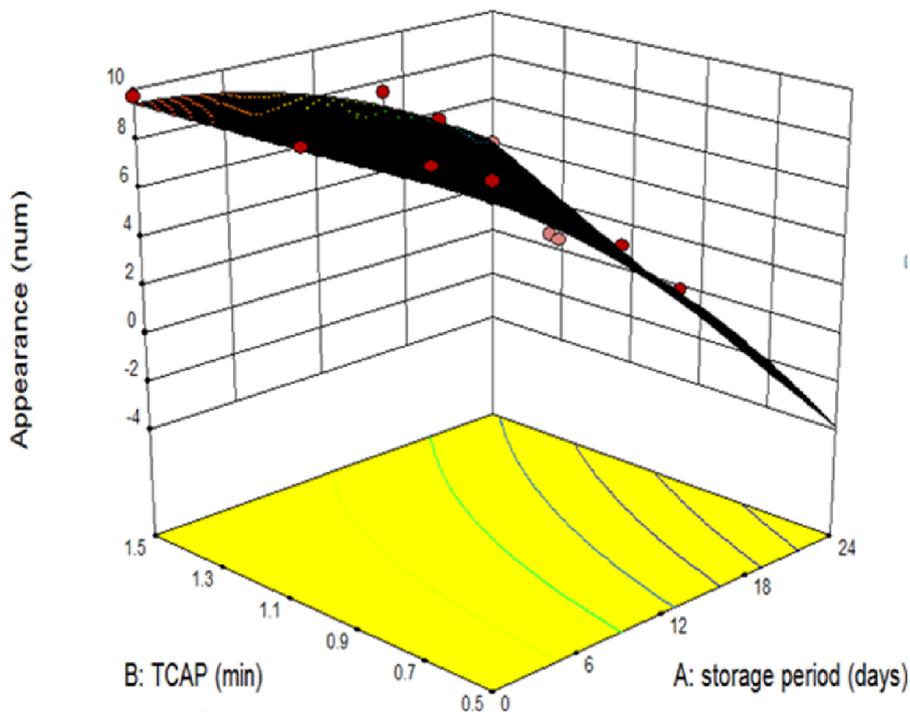


Fig 2. Shows the 3-D Graph Plotted between Appearance, TCAP and SP. For the developed model.

4 CONCLUSION

Thus we get a most fitted model for the function of Appearance with cold atmospheric plasma treatment time (TCAP) and storage period (SP) as the two variants, with  $R^2 = 0.9687$ , F value 61.82 and P value  $<0.0001$ , the suggested model is more significant for the given design data set.

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#### AUTHOR'S BIOGRAPHY

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



## Modeling of Quality (Odor) attribute of the Sliced Chicken as a Function of Period of Storage and Time of Cold Atmospheric Plasma Given

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This paper deals with the developing the most suggested model with  $R^2 = 0.9690$  for Quality (Odor) as a function of the cold plasma treatment time and the storage period for a sliced chicken meat.

**KEYWORDS:** Cold Atmospheric Plasma, Molecular oxygen, Modeling, Ionized gas, Design Expert Software 8.0.

### 1 INTRODUCTION

Poultry carcasses are commonly contaminated with en-teric pathogens such as Salmonella, Campylobacter and *Listeria monocytogenes* (Jacobsreitsma et al., 1994; Murphy et al., 2004); the possibility of cross contamination of poultry carcasses post slaughter is high. Decontamination of poultry carcasses is therefore desirable. Various decontamination technologies have been proposed including the use of various chemical agents such as alkali (Rodriguez et al., 1996), physical methods such as steam treatment (James et al., 2007) and biological control with bacteriophages (Carvalho et al., 2010), but only treat-ment with water supplemented with chlorine or a chlorine-ting agent is used commercially. The effects of such decontaminating treatments are limited (Oyarzabal, 2005; Russell and Axtell, 2005).

#### 1.1 PLASMA SCIENCE

##### 1.1.1 PLASMA- DEFINITION, PHYSICS AND CHEMISTRY

In 1922, the American scientist Irving Langmuir proposed that the electrons, ions and neutrals in an ionized gas could be considered as corpuscular material entrained in some kind of fluid medium and termed this entraining medium "*plasma*", similar to the plasma, introduced by the Czech physiologist Jan Evangelista Purkinje to denote the clear fluid which remains after removal of all the corpuscular material in blood. However, it emerged that there was no "fluid medium" entraining the electrons, ions, and neutrals in an ionized gas (Bellan 2006), nevertheless the name prevailed. The term "*plasma*" refers to a partially or wholly ionized gas composed essentially of photons, ions and free electrons as well as atoms in their fundamental or excited states possessing a net neutral charge. The plasma possesses a net neutral charge because the number of positive charge carriers is equal to the number of negative ones (Kudra and Mujumdar 2009). Electrons and photons are usually designated as "light" species in contrast to the rest of the constituents designated as "heavy" species. Due to its unique properties plasma is often referred to as the fourth state of matter according to a scheme expressing an increase in the energy level from solid to liquid to gas and ultimately to plasma.

##### 1.1.2 TYPES OF PLASMA

Two classes of plasma, namely thermal and NTP can be distinguished on the basis of conditions in which they are generated. This classification of plasma is based on the relative energetic levels of electrons and heavy species of the plasma. NTP (near ambient temperatures of 30-60oC) is obtained at atmospheric or reduced pressures (vacuum) and requires less

power. NTPs are characterised by an electron temperature much above that of the gas (macroscopic temperature) and consequently do not present a local thermodynamic equilibrium. NTP can be generated by an electric discharge in a gas at lower pressure or using microwaves. Typical illustrations for plasma generation at atmospheric pressure include the corona discharge, Dielectric barrier discharges (DBD), Radio-frequency plasmas (RFP) and the gliding arc discharge. In contrast, thermal plasmas are generated at higher pressures, require high power, and an almost thermal equilibrium exists between the electrons and the heavy species. Plasma generation at atmospheric pressure is of interest, both technically and industrially for the food industries because this does not require extreme conditions.

## 1.2 ACTION OF PLASMA ON MICROORGANISMS

### 1.2.1 ACTION ON CELL COMPONENTS AND FUNCTIONS

The use of sterilizing properties of plasma was first introduced towards the end of 60s, patented in 1968 (Menashi 1968) and first works with plasma made from oxygen were proposed in 1989. Thereafter, considerable research has been performed on the mechanism of microbial inactivation by plasma agents. The plasma agents contribute to the lethal action by interacting with the biological material. Nelson and Berger (1989) have shown that O<sub>2</sub> plasma could be a very efficient biocidal against bacteria. Plasma treatment can effectively inactivate a wide range of micro-organisms including spores (Kelly-Wintenberg et al. 1999; Feichtinger et al. 2003; Lee et al. 2006) and viruses (Terrier et al. 2009). Effect of plasma can be quite selective, meaning tuneable between damage to pathogenic organisms without damage to the host, or activation of different pathways in different organisms (Dobrynin et al. 2009). Low-pressure oxygen plasma has been shown to degrade lipids, proteins and DNA of cells (Mogul et al. 2003). The reactive species in plasma have been widely associated to the direct oxidative effects on the outer surface of microbial cells. As an example, commonly used oxygen and nitrogen gas plasma are excellent sources of reactive oxygen-based and nitrogen-based species, such as O•, O<sup>2</sup>, O<sup>3</sup>, OH•, NO•, NO<sub>2</sub> etc.

Atomic oxygen is potentially a very effective sterilizing agent, with a chemical rate constant for oxidation at room temperature of about 106 times that of molecular oxygen (Critzler et al. 2007). These act on the unsaturated fatty acids of the lipid bilayer of the cell membrane, thereby impeding the transport of bio-molecules across it. The double bonds of unsaturated lipids are particularly vulnerable to ozone attack (Guzel-Seydim et al. 2004). Membrane lipids are assumed to be more significantly affected by the reactive oxygen species (ROS) due to their location along the surface of bacterial cell, which allows them to be bombarded by these strong oxidizing agents (Montie et al. 2002). The proteins of the cells and the spores are equally vulnerable to the action of these species, causing denaturation and cell leakage. Oxidation of amino acids and nucleic acids may also cause changes that result in microbial death or injury (Critzler et al. 2007). Micro-organisms in plasma are exposed to an intense bombardment by the radicals most likely provoking surface lesions that the living cell cannot repair sufficiently faster. This may partially explain the observations wherein cells are in many cases destroyed very quickly. This process is termed "etching" (Pelletier 1992). The cell wall rupture has been additionally attributed by Laroussi et al., (2003) and Mendis et al., (2002) to electrostatic forces due to accumulation of charges at the outer surface of cell membranes. The morphological changes in *E. coli* cells treated with atmospheric plasma at 75W for 2 min as observed under an electron microscope by (Hong et al. 2009), clearly revealed that the treated cells had severe cytoplasmic deformations and leakage of bacterial chromosome. These observations demonstrate the loss of viability of bacterial cells after plasma treatment. An analogy between plasma and pulsed electric field has also been drawn to explain the action of plasma on the membranes (Pothakamury et al. 1995; Spilimbergo et al. 2003). It is well established that electroporation of membranes is induced by pulsed electric fields and it appears that plasma acts on similar lines inducing perforations in the membranes of micro-organisms (Sale and Hamilton 1967; Pothakamury et al. 1995; Wouters and Smelt 1997). In addition to generating pores, humid air plasma additionally provokes a marked acidification of the medium (Moreau et al. 2005; Moreau et al. 2007).

### 1.2.2 ROLE OF UV PHOTONS AND CHARGED PARTICLES

The production of UV photons of different wavelengths has been proposed to be involved in dimerizing the thymine bases of DNA including that of spores (Munakata et al. 1991). The role of UV photons in bacterial death when they are submitted to a plasma treatment was reviewed in detail by (Boudam et al. 2006). Recently, by exclusion of reactive particles and spectral fractions of UV radiation from access to the spores Roth et al., (2010) revealed that UV-C radiation is the most effective inactivation agent in the plasma. Ultraviolet (UV) photons play a less important role in atmospheric pressure glow discharge (APGD) because they are easily absorbed by gas atoms and molecules at atmospheric pressure (Vleugels et al. 2005). The role of the charged particles in the bacterial inactivation process was recently investigated by Lu *et al.* (2009). Their work revealed that the charged particles play a minor role in the inactivation process when He/N<sub>2</sub> (3%) is used as working gas than when He/O<sub>2</sub> (3%) is used. Also, they concluded that heat and UV play no or minor roles in the inactivation

process. Similar results were earlier obtained by (Perni et al. 2007) who interplayed bacterial inactivation kinetics with optical emission spectroscopy, and identified oxygen atoms as major contributor in plasma inactivation with minor contributions from UV photons, OH radicals, singlet oxygen metastables and nitric oxide. Thus, a contradiction over the role of UV photons in plasma exists and future studies must be directed to get a clear picture.

### **1.2.3 EFFECT OF PROCESS PARAMETERS**

The concentrations in which the plasma agents occur in plasma depend greatly on the device set-up (reactor geometry), operating conditions (gas pressure, type, flow, frequency and power of plasma excitation) and gas composition which affect their efficacy in a process when employed. To cite an example, the destructive efficiency of various gas plasma sources and temperatures on *Bacillus spp.* spores were compared by (Hury et al. 1998). This group demonstrated that oxygen-based plasma is more efficient than pure argon plasma. Another deciding criterion is whether the substrate to be sterilized is in direct contact with the plasma (*Direct Exposure*) or located remote from it (*Remote Exposure*) (Moisan et al. 2001; Laroussi 2005; Boudam et al. 2006). If exposed remotely, the quantum of heat transmitted to a sample is reduced, the charged particles do not play a role since they recombine before reaching the sample, and many of the short-lived neutral reactive species also do not reach the sample. Since, the components of the plasma are reactive and self-quenching, with a relatively short half-life, decreased time of flight would be expected to be one of the major factors in antimicrobial efficacy in this case (Niemira and Sites 2008). By varying the process parameters involved in plasma generation, a multitude of mechanisms can be actuated which may act individually or synergistically.

Nevertheless, the details of interaction of the different plasma agents with the different components of bacterial cells or spores are currently very limited. The interactions which occur between plasma agents and biological materials, ultimately leading to sterilization are still under investigation.

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the Odor of CPT sliced chicken as a function of the cold plasma treatment time and the storage period of treated sliced chicken meat.

## **2 MATERIALS AND METHODS**

<sup>26</sup>Sliced chicken were purchased from local market (Benha, Qaliobia governorate, Egypt). All samples were transported to our laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts for counts of total bacteria, psychrophilic bacteria, spore forming bacteria, total molds and yeasts. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

### **2.1 PLASMA TREATMENTS CHARACTER OF EXPOSURE MACHINE**

The plasma generator consisted of a negative dc source, a Blumlein-type pulse-forming network (E-PFN), and a dynamic spark gap switch. A triggered spark gap switch was used as a closing switch of E-PFN. E-PFN had four stages of LC ladder, which were composed of 5 nF of capacitor and 3 μH of inductor. The characteristic impedance ( $2\sqrt{L/C}$ ) and the pulse width ( $2\sqrt{LC}$ ) of E-PFN, calculated from capacitance (C) and inductance (L) of the LC ladder, and number (N) of LC ladder stages were approximately 49 Ω and 1.0 μs, respectively.

A charging resistance value of 50 kΩ was chosen in the present case which corresponds to a charging RC time constant of 1 ms, which is 40 times faster compared to the repetition rate of the pulse. A schematic of the pulsed atmospheric-pressure plasma jet (PAPPJ) device for generating high voltage pulsed, cold atmospheric plasma jets is shown in Figure 1. The high voltage (HV) wire electrode, which is made of a copper wire, is inserted into a hollow barrel of a syringe. The distance between the tip of the HV electrode and the nozzle is 0.5 cm. When HV pulsed, DC voltage (amplitudes up to 25 kV, repetition rate up to 25 Hz), was applied to the HV electrode and helium gas was injected into the hollow barrel. This device was made using medical syringe (made out of an insulating material cylinder). The gas was fed into the system via flow

meter. The applied voltage to and the discharge current through the discharge chamber were measured using a voltage divider (Homemade), which was connected between the two electrodes, and a current monitor, which can be located upon returning to the ground. The signals from the voltage divider and the current monitor were recorded in a digitizing oscilloscope (Lecroy, USA) with a 200-MHz bandwidth. The high voltage pulses are applied between the needle electrode positioned inside a dielectric cylinder (a simple medical syringe) and a metal ring placed on the exterior of this cylinder. In order to obtain electric discharges at atmospheric pressure, a high voltage pulses (tens of kV) which have limited duration (hundreds of nanoseconds) and are repeated (tens of pulses per second), in addition to an inert gas (argon) is introduced in the cylinder.

The gas flows were in the range 0.5-10 l/min. The discharge takes place between the metallic needle top and a metallic ring fit on the outer surface of the syringe. Under optimal conditions, plasma is emitted as centimeter-long jets, just millimeters in diameter or even smaller. The working gases are supplied by high-pressure cylinders. Gas pressure regulators are used to reduce the pressure of gases to a workable level. Then, gas flow controllers deliver the gases with the desired flow. For voltage amplitudes of 15-18 kV, the plasma jet is very weak. The plasma jet disappears for voltage amplitudes lower than 15 kV. When argon is injected from the gas inlet and high voltage pulses, 26 kV voltages is applied to the electrode, the plasma jet is generated and a plasma plume reaching length of 21 mm is launched through the end of the tube and in the surrounding air. The length of the plasma plume can be adjusted by the gas flow rate and the applied voltage. Three bags from each of sliced chicken were exposed to plasma at 0.5, 1.0 and 1.5 min in Plasma Physics and Nuclear Fusion Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Cairo, Egypt. After the exposure time of plasma, all samples were stored at  $4\pm 1^\circ\text{C}$ .

## 2.2 SENSORY ANALYSIS<sup>26</sup>

## 2.3 STATISTICAL ANALYSIS<sup>26</sup>

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was  $P \leq 0.05$ .

The experimental data<sup>26</sup> obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations: like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_j x_j + \sum \beta_{jj} x_j^2 + \sum \beta_{ij} x_i x_j$ , where  $y$  is the response,  $x_i$  and  $x_j$  are the uncoded independent variables (factors), and  $\beta_0$ ,  $\beta_i$  &  $\beta_j$ ,  $\beta_{ii}$  &  $\beta_{jj}$  and  $\beta_{ij}$  are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs. In this the Sensory Attribute (Odor) was the response and the dependent two factors were the Storage time and the cold atmospheric plasma treatment time given to the sliced chicken.

## 3 RESULT AND DISCUSSION

The result of statistical Analysis are shown below:

*Table 1. shows the fit summary the models*

Summary (detailed tables shown below)

	Sequential	Lack of Fit	Adjusted	Predicted	
Source	p-value	p-value	R-Squared	R-Squared	
Linear	< 0.0001		0.8462	0.7915	
2FI	0.0028		0.9230	0.8827	
<u>Quadratic</u>	<u>0.0321</u>		<u>0.9535</u>	<u>0.9242</u>	<u>Suggested</u>
Cubic	0.0427		0.9779	0.9021	Aliased

Table 2. Shows the model sum of square

Sequential Model Sum of Squares [Type I]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	819.53	1	819.53			
Linear vs Mean	52.04	2	26.02	42.25	< 0.0001	
2FI vs Linear	4.31	1	4.31	13.97	0.0028	
<u>Quadratic vs 2</u>	<u>1.84</u>	<u>2</u>	<u>0.92</u>	<u>4.95</u>	<u>0.0321</u>	<u>Suggested</u>
Cubic vs Quad	1.24	3	0.41	4.67	0.0427	Aliased
Residual	0.62	7	0.088			
Total	879.58	16	54.97			

Table 3. Model summary Statistics

Model Summary Statistics

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	0.78	0.8667	0.8462	0.7915	12.52	
2FI	0.56	0.9384	0.9230	0.8827	7.05	
<u>Quadratic</u>	<u>0.43</u>	<u>0.9690</u>	<u>0.9535</u>	<u>0.9242</u>	<u>4.55</u>	<u>Suggested</u>
Cubic	0.30	0.9897	0.9779	0.9021	5.88	Aliased

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

Analysis of variance table [Partial sum of squares - Type III]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	58.19	5	11.64	62.57	< 0.0001	significant
A-storage pe.	37.25	1	37.25	200.30	< 0.0001	
B-TCAP	15.10	1	15.10	81.21	< 0.0001	
AB	5.65	1	5.65	30.37	0.0003	
A <sup>2</sup>	1.80	1	1.80	9.66	0.0111	
B <sup>2</sup>	0.039	1	0.039	0.21	0.6574	
Residual	1.86	10	0.19			
Cor Total	60.04	15				

The Model F-value of 62.57 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Table 5. ANNOVA Summary

Std. Dev.	0.43	R-Squared	0.9690
Mean	7.16	Adj R-Squared	0.9535
C.V. %	6.03	Pred R-Square	0.9242
PRESS	4.55	Adeq Precisor	20.573

The "Pred R-Squared" of 0.9242 is in reasonable agreement with the "Adj R-Squared" of 0.9535; i.e. the difference is less than 0.2.

The developed Fit Suggested required Model in term of Coded Factors:

#### Final Equation in Terms of Coded Factors:

$$\begin{aligned} \text{odor} = & \\ & +5.88 \\ & -4.65 * A \\ & +1.93 * B \\ & +1.94 * AB \\ & -1.19 * A^2 \\ & +0.11 * B^2 \end{aligned}$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The developed Fit Suggested required Model in term of Actual Factors:

Final Equation in Terms of Actual Factors:

$$\begin{aligned} \text{odor} = & \\ & +9.79879 \\ & -0.51312 * \text{storage period} \\ & -0.89939 * \text{TCAP} \\ & +0.32315 * \text{storage period} * \text{TCAP} \\ & -8.23131\text{E-}003 * \text{storage period}^2 \\ & +0.44459 * \text{TCAP}^2 \end{aligned}$$

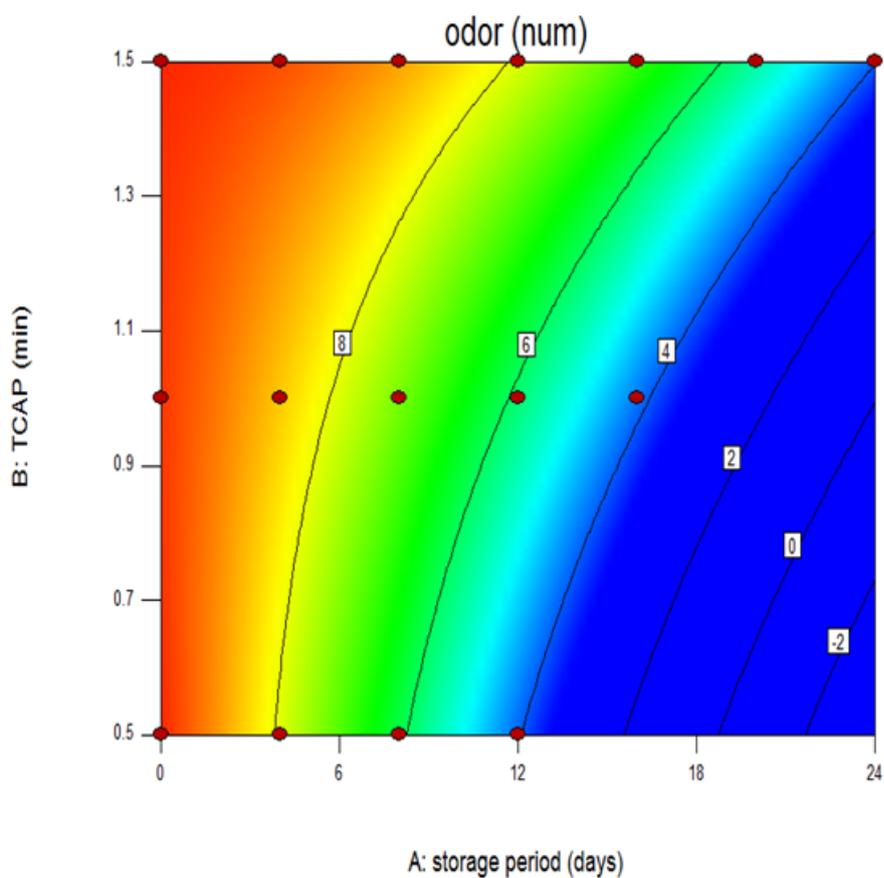


Fig 1. Shows the Contour Graph for the developed Model.

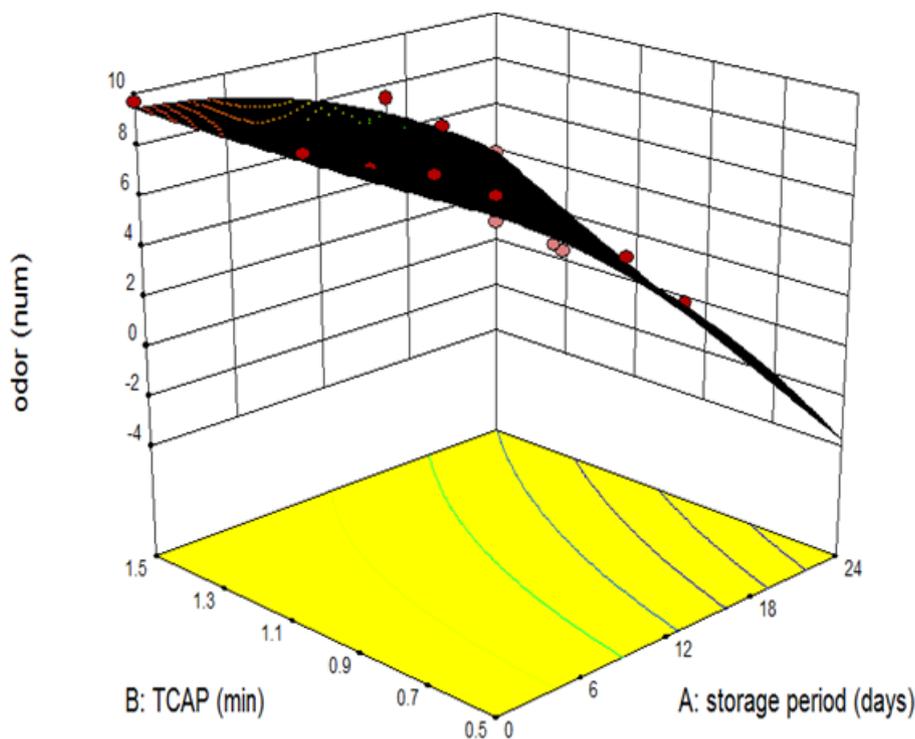


Fig 2. Shows the 3-D Graph Plotted between Odor, TCAP and SP. For the developed model.

#### 4 CONCLUSION

Thus we get a most fitted model for the function of Quality attribute (Odor) with cold atmospheric plasma treatment time (TCAP) and storage period (SP) as the two variants, with  $R^2 = 0.9690$ , F value 62.57 and P value  $<0.0001$ , the suggested model is more significant for the given design data set.

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**AUTHOR'S BIOGRAPHY**

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



## Modeling of Quality (Texture) attribute of the Sliced Chicken as a Function of Period of Storage and Time of Cold Atmospheric Plasma Given

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This paper deals with the developing the most suggested model with  $R^2 = 0.9601$  for Quality (Texture) as a function of the cold plasma treatment time and the storage period for a sliced chicken meat.

**KEYWORDS:** Cold Atmospheric Plasma, Molecular oxygen, Modeling, Ionized gas, Design Expert Software 8.0.

### 1 INTRODUCTION

Poultry carcasses are commonly contaminated with en-teric pathogens such as Salmonella, Campylobacter and *Listeria monocytogenes* (Jacobsreitsma et al., 1994; Murphy et al., 2004); the possibility of cross contamination of poultry carcasses post slaughter is high. Decontamination of poultry carcasses is therefore desirable. Various decontamination technologies have been proposed including the use of various chemical agents such as alkali (Rodriguez et al., 1996), physical methods such as steam treatment (James et al., 2007) and biological control with bacteriophages (Carvalho et al., 2010), but only treat-ment with water supplemented with chlorine or a chlorine-ting agent is used commercially. The effects of such decontaminating treatments are limited (Oyarzabal, 2005; Russell and Axtell, 2005).

#### 1.1 PLASMA SCIENCE

##### 1.1.1 PLASMA- DEFINITION, PHYSICS AND CHEMISTRY

In 1922, the American scientist Irving Langmuir proposed that the electrons, ions and neutrals in an ionized gas could be considered as corpuscular material entrained in some kind of fluid medium and termed this entraining medium "*plasma*", similar to the plasma, introduced by the Czech physiologist Jan Evangelista Purkinje to denote the clear fluid which remains after removal of all the corpuscular material in blood. However, it emerged that there was no "fluid medium" entraining the electrons, ions, and neutrals in an ionized gas (Bellan 2006), nevertheless the name prevailed. The term "*plasma*" refers to a partially or wholly ionized gas composed essentially of photons, ions and free electrons as well as atoms in their fundamental or excited states possessing a net neutral charge. The plasma possesses a net neutral charge because the number of positive charge carriers is equal to the number of negative ones (Kudra and Mujumdar 2009). Electrons and photons are usually designated as "light" species in contrast to the rest of the constituents designated as "heavy" species. Due to its unique properties plasma is often referred to as the fourth state of matter according to a scheme expressing an increase in the energy level from solid to liquid to gas and ultimately to plasma.

##### 1.1.2 TYPES OF PLASMA

Two classes of plasma, namely thermal and NTP can be distinguished on the basis of conditions in which they are generated. This classification of plasma is based on the relative energetic levels of electrons and heavy species of the plasma. NTP (near ambient temperatures of 30-60oC) is obtained at atmospheric or reduced pressures (vacuum) and requires less

power. NTPs are characterised by an electron temperature much above that of the gas (macroscopic temperature) and consequently do not present a local thermodynamic equilibrium. NTP can be generated by an electric discharge in a gas at lower pressure or using microwaves. Typical illustrations for plasma generation at atmospheric pressure include the corona discharge, Dielectric barrier discharges (DBD), Radio-frequency plasmas (RFP) and the gliding arc discharge. In contrast, thermal plasmas are generated at higher pressures, require high power, and an almost thermal equilibrium exists between the electrons and the heavy species. Plasma generation at atmospheric pressure is of interest, both technically and industrially for the food industries because this does not require extreme conditions.

## 1.2 ACTION OF PLASMA ON MICROORGANISMS

### 1.2.1 ACTION ON CELL COMPONENTS AND FUNCTIONS

The use of sterilizing properties of plasma was first introduced towards the end of 60s, patented in 1968 (Menashi 1968) and first works with plasma made from oxygen were proposed in 1989. Thereafter, considerable research has been performed on the mechanism of microbial inactivation by plasma agents. The plasma agents contribute to the lethal action by interacting with the biological material. Nelson and Berger (1989) have shown that O<sub>2</sub> plasma could be a very efficient biocidal against bacteria. Plasma treatment can effectively inactivate a wide range of micro-organisms including spores (Kelly-Wintenberg et al. 1999; Feichtinger et al. 2003; Lee et al. 2006) and viruses (Terrier et al. 2009). Effect of plasma can be quite selective, meaning tuneable between damage to pathogenic organisms without damage to the host, or activation of different pathways in different organisms (Dobrynin et al. 2009). Low-pressure oxygen plasma has been shown to degrade lipids, proteins and DNA of cells (Mogul et al. 2003). The reactive species in plasma have been widely associated to the direct oxidative effects on the outer surface of microbial cells. As an example, commonly used oxygen and nitrogen gas plasma are excellent sources of reactive oxygen-based and nitrogen-based species, such as O•, O<sup>2</sup>, O<sup>3</sup>, OH•, NO•, NO<sub>2</sub> etc.

Atomic oxygen is potentially a very effective sterilizing agent, with a chemical rate constant for oxidation at room temperature of about 106 times that of molecular oxygen (Critzler et al. 2007). These act on the unsaturated fatty acids of the lipid bilayer of the cell membrane, thereby impeding the transport of bio-molecules across it. The double bonds of unsaturated lipids are particularly vulnerable to ozone attack (Guzel-Seydim et al. 2004). Membrane lipids are assumed to be more significantly affected by the reactive oxygen species (ROS) due to their location along the surface of bacterial cell, which allows them to be bombarded by these strong oxidizing agents (Montie et al. 2002). The proteins of the cells and the spores are equally vulnerable to the action of these species, causing denaturation and cell leakage. Oxidation of amino acids and nucleic acids may also cause changes that result in microbial death or injury (Critzler et al. 2007). Micro-organisms in plasma are exposed to an intense bombardment by the radicals most likely provoking surface lesions that the living cell cannot repair sufficiently faster. This may partially explain the observations wherein cells are in many cases destroyed very quickly. This process is termed "etching" (Pelletier 1992). The cell wall rupture has been additionally attributed by Laroussi et al., (2003) and Mendis et al., (2002) to electrostatic forces due to accumulation of charges at the outer surface of cell membranes. The morphological changes in *E. coli* cells treated with atmospheric plasma at 75W for 2 min as observed under an electron microscope by (Hong et al. 2009), clearly revealed that the treated cells had severe cytoplasmic deformations and leakage of bacterial chromosome. These observations demonstrate the loss of viability of bacterial cells after plasma treatment. An analogy between plasma and pulsed electric field has also been drawn to explain the action of plasma on the membranes (Pothakamury et al. 1995; Spilimbergo et al. 2003). It is well established that electroporation of membranes is induced by pulsed electric fields and it appears that plasma acts on similar lines inducing perforations in the membranes of micro-organisms (Sale and Hamilton 1967; Pothakamury et al. 1995; Wouters and Smelt 1997). In addition to generating pores, humid air plasma additionally provokes a marked acidification of the medium (Moreau et al. 2005; Moreau et al. 2007).

### 1.2.2 ROLE OF UV PHOTONS AND CHARGED PARTICLES

The production of UV photons of different wavelengths has been proposed to be involved in dimerizing the thymine bases of DNA including that of spores (Munakata et al. 1991). The role of UV photons in bacterial death when they are submitted to a plasma treatment was reviewed in detail by (Boudam et al. 2006). Recently, by exclusion of reactive particles and spectral fractions of UV radiation from access to the spores Roth et al., (2010) revealed that UV-C radiation is the most effective inactivation agent in the plasma. Ultraviolet (UV) photons play a less important role in atmospheric pressure glow discharge (APGD) because they are easily absorbed by gas atoms and molecules at atmospheric pressure (Vleugels et al. 2005). The role of the charged particles in the bacterial inactivation process was recently investigated by Lu *et al.* (2009). Their work revealed that the charged particles play a minor role in the inactivation process when He/N<sub>2</sub> (3%) is used as working gas than when He/O<sub>2</sub> (3%) is used. Also, they concluded that heat and UV play no or minor roles in the inactivation

process. Similar results were earlier obtained by (Perni et al. 2007) who interplayed bacterial inactivation kinetics with optical emission spectroscopy, and identified oxygen atoms as major contributor in plasma inactivation with minor contributions from UV photons, OH radicals, singlet oxygen metastables and nitric oxide. Thus, a contradiction over the role of UV photons in plasma exists and future studies must be directed to get a clear picture.

### **1.2.3 EFFECT OF PROCESS PARAMETERS**

The concentrations in which the plasma agents occur in plasma depend greatly on the device set-up (reactor geometry), operating conditions (gas pressure, type, flow, frequency and power of plasma excitation) and gas composition which affect their efficacy in a process when employed. To cite an example, the destructive efficiency of various gas plasma sources and temperatures on *Bacillus spp.* spores were compared by (Hury et al. 1998). This group demonstrated that oxygen-based plasma is more efficient than pure argon plasma. Another deciding criterion is whether the substrate to be sterilized is in direct contact with the plasma (*Direct Exposure*) or located remote from it (*Remote Exposure*) (Moisan et al. 2001; Laroussi 2005; Boudam et al. 2006). If exposed remotely, the quantum of heat transmitted to a sample is reduced, the charged particles do not play a role since they recombine before reaching the sample, and many of the short-lived neutral reactive species also do not reach the sample. Since, the components of the plasma are reactive and self-quenching, with a relatively short half-life, decreased time of flight would be expected to be one of the major factors in antimicrobial efficacy in this case (Niemira and Sites 2008). By varying the process parameters involved in plasma generation, a multitude of mechanisms can be actuated which may act individually or synergistically.

Nevertheless, the details of interaction of the different plasma agents with the different components of bacterial cells or spores are currently very limited. The interactions which occur between plasma agents and biological materials, ultimately leading to sterilization are still under investigation.

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system.

The objective of the study is modeling of the Texture of CPT sliced chicken as a function of the cold plasma treatment time and the storage period of treated sliced chicken meat.

## **2 MATERIALS AND METHODS**

<sup>26</sup>Sliced chicken were purchased from local market (Benha, Qaliobia governorate, Egypt). All samples were transported to our laboratory food irradiation unit, Nuclear Research Center in ice-box (0°C) and surveyed for microbiological counts for counts of total bacteria, psychrophilic bacteria, spore forming bacteria, total molds and yeasts. Then, sliced chicken samples were packed in tightly sealed polyethylene pouches and divided into seven groups and stored in freezing till irradiation treatments.

### **2.1 PLASMA TREATMENTS CHARACTER OF EXPOSURE MACHINE**

The plasma generator consisted of a negative dc source, a Blumlein-type pulse-forming network (E-PFN), and a dynamic spark gap switch. A triggered spark gap switch was used as a closing switch of E-PFN. E-PFN had four stages of LC ladder, which were composed of 5 nF of capacitor and 3 μH of inductor. The characteristic impedance ( $2\sqrt{L/C}$ ) and the pulse width ( $2\sqrt{LC}$ ) of E-PFN, calculated from capacitance (C) and inductance (L) of the LC ladder, and number (N) of LC ladder stages were approximately 49 Ω and 1.0 μs, respectively.

A charging resistance value of 50 kΩ was chosen in the present case which corresponds to a charging RC time constant of 1 ms, which is 40 times faster compared to the repetition rate of the pulse. A schematic of the pulsed atmospheric-pressure plasma jet (PAPPJ) device for generating high voltage pulsed, cold atmospheric plasma jets is shown in Figure 1. The high voltage (HV) wire electrode, which is made of a copper wire, is inserted into a hollow barrel of a syringe. The distance between the tip of the HV electrode and the nozzle is 0.5 cm. When HV pulsed, DC voltage (amplitudes up to 25 kV, repetition rate up to 25 Hz), was applied to the HV electrode and helium gas was injected into the hollow barrel. This device was made using medical syringe (made out of an insulating material cylinder). The gas was fed into the system via flow

meter. The applied voltage to and the discharge current through the discharge chamber were measured using a voltage divider (Homemade), which was connected between the two electrodes, and a current monitor, which can be located upon returning to the ground. The signals from the voltage divider and the current monitor were recorded in a digitizing oscilloscope (Lecroy, USA) with a 200-MHz bandwidth. The high voltage pulses are applied between the needle electrode positioned inside a dielectric cylinder (a simple medical syringe) and a metal ring placed on the exterior of this cylinder. In order to obtain electric discharges at atmospheric pressure, a high voltage pulses (tens of kV) which have limited duration (hundreds of nanoseconds) and are repeated (tens of pulses per second), in addition to an inert gas (argon) is introduced in the cylinder.

The gas flows were in the range 0.5-10 l/min. The discharge takes place between the metallic needle top and a metallic ring fit on the outer surface of the syringe. Under optimal conditions, plasma is emitted as centimeter-long jets, just millimeters in diameter or even smaller. The working gases are supplied by high-pressure cylinders. Gas pressure regulators are used to reduce the pressure of gases to a workable level. Then, gas flow controllers deliver the gases with the desired flow. For voltage amplitudes of 15-18 kV, the plasma jet is very weak. The plasma jet disappears for voltage amplitudes lower than 15 kV. When argon is injected from the gas inlet and high voltage pulses, 26 kV voltages is applied to the electrode, the plasma jet is generated and a plasma plume reaching length of 21 mm is launched through the end of the tube and in the surrounding air. The length of the plasma plume can be adjusted by the gas flow rate and the applied voltage. Three bags from each of sliced chicken were exposed to plasma at 0.5, 1.0 and 1.5 min in Plasma Physics and Nuclear Fusion Department, Nuclear Research Center, Atomic Energy Authority, Inshas, Cairo, Egypt. After the exposure time of plasma, all samples were stored at  $4\pm 1^\circ\text{C}$ .

## 2.2 SENSORY ANALYSIS<sup>26</sup>

## 2.3 STATISTICAL ANALYSIS<sup>26</sup>

The statistical evaluation of the mean data was compared using one-way analysis of variance (ANOVA) according to Zar (1984). The chosen level of significance was  $P \leq 0.05$ .

The experimental data<sup>26</sup> obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations: like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2 + \sum \beta_j x_j + \sum \beta_{jj} x_j^2 + \sum \beta_{ij} x_i x_j$ , where  $y$  is the response,  $x_i$  and  $x_j$  are the uncoded independent variables (factors), and  $\beta_0$ ,  $\beta_i$  &  $\beta_j$ ,  $\beta_{ii}$  &  $\beta_{jj}$  and  $\beta_{ij}$  are intercept, linear, quadratic, and interaction constant coefficients, respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variables which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs. In this the Sensory Attribute (Texture) was the response and the dependent two factors were the Storage time and the cold atmospheric plasma treatment time given to the sliced chicken.

## 3 RESULT AND DISCUSSION

The result of statistical Analysis are shown below:

*Table 1. shows the fit summary the models*

Summary (detailed tables shown below)

Source	Sequential p-value	Lack of Fit p-value	Adjusted R-Squared	Predicted R-Squared	
Linear	< 0.0001		0.8342	0.7660	
<u>2FI</u>	<u>0.0001</u>		<u>0.9501</u>	<u>0.9223</u>	<u>Suggested</u>
Quadratic	0.0732		0.9645	0.9366	
Cubic	0.1039		0.9778	0.9066	Aliased

Table 2. Shows the model sum of square

Sequential Model Sum of Squares [Type I]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	671.20	1	671.20			
Linear vs Mear	49.60	2	24.80	38.73	< 0.0001	
<u>2FI vs Linear</u>	<u>6.01</u>	<u>1</u>	<u>6.01</u>	<u>31.18</u>	<u>0.0001</u>	<u>Suggested</u>
Quadratic vs 2	0.94	2	0.47	3.43	0.0732	
Cubic vs Quad	0.77	3	0.26	3.01	0.1039	Aliased
Residual	0.60	7	0.086			
Total	729.12	16	45.57			

Table 3. Model summary Statistics

Model Summary Statistics

Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	0.80	0.8563	0.8342	0.7660	13.55	
<u>2FI</u>	<u>0.44</u>	<u>0.9601</u>	<u>0.9501</u>	<u>0.9223</u>	<u>4.50</u>	<u>Suggested</u>
Quadratic	0.37	0.9763	0.9645	0.9366	3.67	
Cubic	0.29	0.9897	0.9778	0.9066	5.41	Aliased

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 4. Shows the ANNOVA tables

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	55.61	3	18.54	96.15	< 0.0001	significant
A-storage pe.	49.60	1	49.60	257.30	< 0.0001	
B-TCAP	16.52	1	16.52	85.69	< 0.0001	
AB	6.01	1	6.01	31.18	0.0001	
Residual	2.31	12	0.19			
Cor Total	57.93	15				

The Model F-value of 96.15 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Table 5. ANNOVA Summary

Std. Dev.	0.44	R-Squared	0.9601
Mean	6.48	Adj R-Squared	0.9501
C.V. %	6.78	Pred R-Square	0.9223
PRESS	4.50	Adeq Precisor	26.354

The "Pred R-Squared" of 0.9223 is in reasonable agreement with the "Adj R-Squared" of 0.9501; i.e. the difference is less than 0.2.

The developed Fit Suggested required Model in term of Coded Factors:

#### Final Equation in Terms of Coded Factors:

$$\begin{aligned} \text{Texture} = & \\ & +5.04 \\ & -4.05 * A \\ & +1.65 * B \\ & +1.57 * AB \end{aligned}$$

The equation in terms of coded factors can be used to make predictions about the response for given levels of each factor. By default, the high levels of the factors are coded as +1 and the low levels of the factors are coded as -1. The coded equation is useful for identifying the relative impact of the factors by comparing the factor coefficients.

The developed Fit Suggested required Model in term of Actual Factors:

Final Equation in Terms of Actual Factors:

$$\begin{aligned} \text{Texture} = & \\ & +8.92811 \\ & -0.59914 * \text{storage period} \\ & +0.16542 * \text{TCAP} \\ & +0.26156 * \text{storage period} * \text{TCAP} \end{aligned}$$

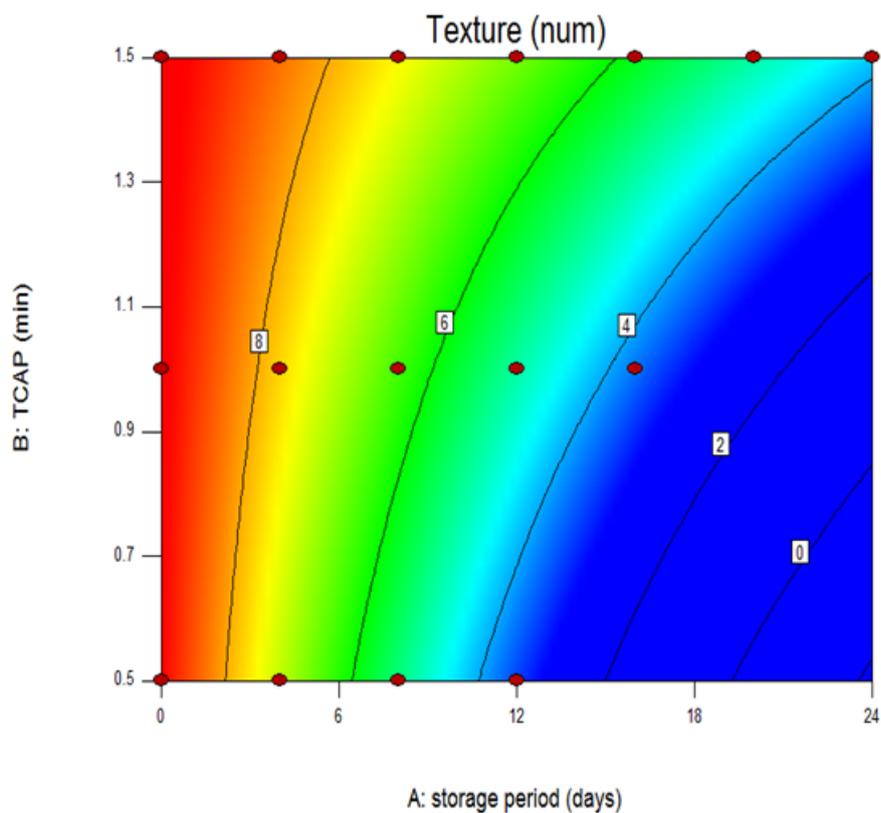


Fig 1. Shows the Contour Graph for the developed Model.

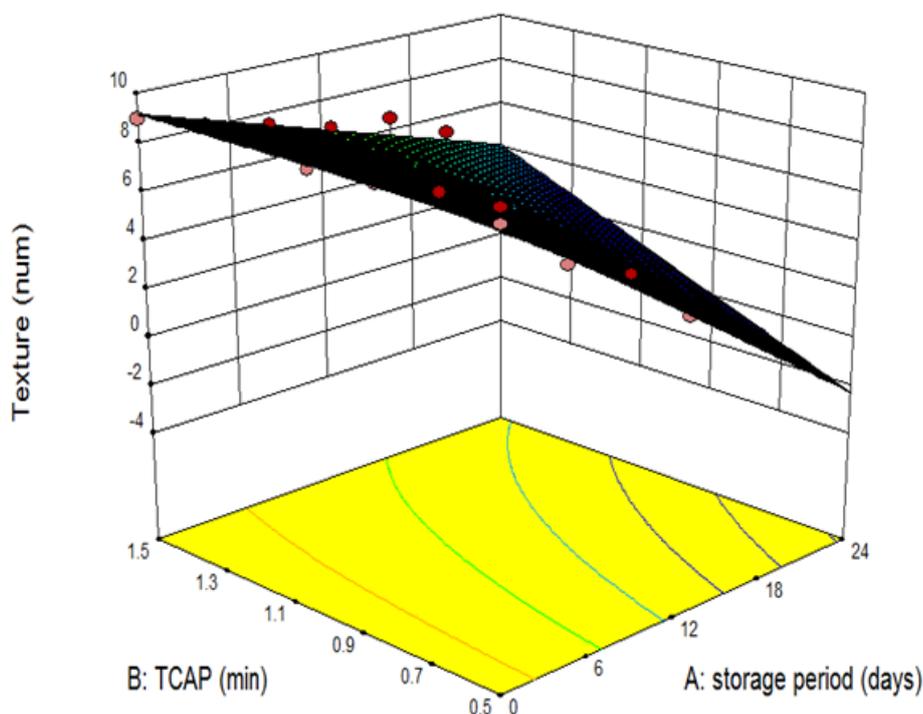


Fig 2. Shows the 3-D Graph Plotted between Texture, TCAP and SP. For the developed model.

#### 4 CONCLUSION

Thus we get a most fitted model for the function of Quality attribute (Texture) with cold atmospheric plasma treatment time (TCAP) and storage period (SP) as the two variants, with  $R^2 = 0.9601$ , F value 92.15 and P value  $<0.0001$ , the suggested model is more significant for the given design data set.

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**AUTHOR'S BIOGRAPHY**

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



## Mathematical Modeling of Degree of Thermal Oxidation of Edible Oil (Rape seed) as a Function of Induction Time at Fixed Induced Power During Microwave Heating

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This is about relating the thermal induction time range from 0-40 minutes for Rape seed oil (refined) of definite composition with the change in the thermal oxidation by the models developed by using M S Excel and Statistical Software, Design Expert Software 8.0 with there  $R^2$ . And through analysis of prepared model data with their plotted graph.

**KEYWORDS:** Thermal Oxidation, Peroxide value, Design Expert Software 8.0, M S Excel, Microwave Oven, Modeling.

### 1 INTRODUCTION

Thermal oxidation of edible oil is an important determination of the quality of edible oil. During processing of food stuffs involving the use of edible oils such as blended oil as a heat transfer medium, the oil owing to high temperature undergoes thermal oxidation over a period of time. Due to the thermal oxidation of edible oils, they become unfit for further use after a period of time. Hence proper control of processing condition is a desirable requirement in order to delay the onset of thermal oxidation of edible oil.

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system. Mathematical models in the field of oxidation of edible oils can enable the determination of time of cook of edible oil which would lead to the least amount of oxidation of edible oil during processing using edible oils as a heating medium.

Mathematical models can enable the optimization of frying time at fixed power to reduce the rancidity of frying oils. In light of above considerations the study was conducted in order to attain the following objective

- 1) To determine the relationship of the Thermal oxidation as function of Induction time of the frying oil at fixed power during microwave cooking

Heating is an important part of many food processing operations. Many desirable changes, as well as undesirable reactions, occur in vegetable oils when they are heated at elevated temperature. However, during heating, vegetable oils are very sensitive and susceptible to quality changes, caused by chemical instability, that are dependent on both chemical composition and environmental factors. Lipid oxidation is one of the major deleterious reactions during heating that markedly affects the quality of vegetable oils. This chemical reaction is of primary concern to many researchers in the field of fats and oils. The extensive studies on lipid oxidation have spurred a vast array of findings in the field of fats and oils processing. Today, it is well known that this deleterious reaction leads to the formation of various oxidation products, which may result in the oil and fat products becoming unfit for human consumption. Compositional and/or environmental effects on lipid oxidation can be expressed by a mathematical relationship. However, this relationship applies only to several simple

food systems and reactions. More often, oxidative reactions of vegetable oils are more complex and unique in their behavior, and the appropriate model must be derived individually for each product and oil system. Temperature is one of the main environmental factors that influence the rate of quality loss. The dependence on temperature of most reactions in foods can be expressed more precisely by the Arrhenius model.

Shahidi and Spurvey (1996) stated that Autoxidation of oils and the decomposition of hydroperoxides increase as the temperature increases. Velasco and Dobarganes (2002) stated that the formation of autoxidation products during the induction period is slow at low temperature. The concentration of the hydroperoxides increases until the advanced stages of oxidation. Marquez-Ruiz *et al.* (1996) suggested that The content of polymerized compounds increases significantly at the end of the induction period of autoxidation. Yang and Min (1994); Rahmani and Saari Csallani (1998) suggested that temperature has little effect on oil oxidation due to the low activation energy of 0 to 6 kcal/mole. Sattar *et al.* (1976) stated that light is much more important than temperature in oil oxidation.

## 2 MATERIALS AND METHODS

### 2.1 EDIBLE RAPE SEED OIL COMPOSITION.

**Table 1.** <sup>19</sup> *Composition of Refined Rape Seed Oil used.*

Component	Oil Type
	rapeseed
<b>Main fatty acids (% of peak area)</b>	
Palmitic	2
Stearic	2
C <sub>20</sub> -C <sub>22</sub> saturated	2
Monoenoic	49
Dienoic	34
Trienoic	8
Eicosenoic	1.5
Trans-unsaturated	0.5
Peroxide value (meq/kg)	0.58
Acid value (mg/g)	0.07
Conjugated dienes (% m/m)	0.4
Polar compounds (% m/m)	0.8
<b>Tocopherols (mg/kg)</b>	
Tocopherol $\alpha$	294
Tocopherol $\beta+\gamma$	392
Tocopherol $\delta$	12
Total tocopherols	698

### 2.2 PREPARATION OF SAMPLES (REFERENCE [19])

### 2.3 SAMPLE COLLECTION (REFERENCE [19])

\*Assumptions

- Surface area exposed to atmosphere is constant or same.
- No mixing or agitation.

### 2.4 MEASUREMENT OF OXIDATION

#### **2.4.1 PEROXIDE VALUE (PV) ANALYTICAL METHOD.**

##### **2.4.1.1 PURPOSE AND SCOPE**

This method describes the determination of peroxides values for vegetable oils and fats. The peroxide value is a parameter specifying the content of oxygen as peroxide, especially hydro peroxides in a substance. The peroxide value is a measure of the oxidation present.

##### **2.4.1.2 PRINCIPLE**

The sample treated in the solution with a mixture of acetic acid and a suitable organic solvent and then with a solution of potassium iodide. The liberated iodine is titrated with a standard solution of sodium thiosulphate.

Peroxides and similar products which oxidize potassium iodide under the conditions of the test will contribute to the peroxide value. Variations in procedure may affect the results. Peroxide values are expressed either in milliequivalents of peroxide/kg or millimoles of peroxide/l.

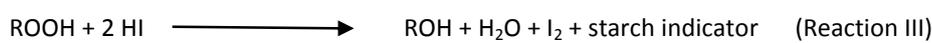
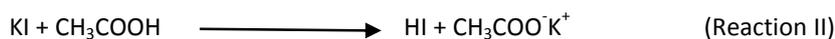
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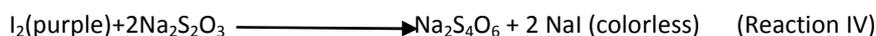
Generation of hydroperoxides:



Generation of iodine:



Titration step:



Reaction of peroxides of the structures R-O-O-R' and

R-CH-O-O-CH-R' follows an analogous pathway. Whilst cyclic peroxides do not react quantitatively under the conditions described here.

Alternatively, the ion reaction is of more of general applicability:



##### **2.4.1.4 PROCEDURE**

- i) Approx. 3.0g of the sample was transferred, accurately weighed, into a 250 ml conical flask.
- ii) 25 ml of the appropriate solvent mixture (glacial acetic acid: chloroform, 1:2) and 1 ml saturated potassium iodide solution freshly prepared was added.
- iii) Was Allowed to react for 60 sec. and shaking thoroughly during this period. Then 35 ml of distilled water was added.
- iv) Then was titrated with 0.001 N sodium thiosulphate solution using 0.5 ml 1%starch solution as indicator.
- v) During the titration shaken until the blue color disappeared.
- vi) Blank titration was carried under the same conditions.

### 2.4.1.5 CALCULATIONS

S=titration of sample.

B=titration of blank.

SW=weight of sample taken.(gm)

N=normality of sodium thiosulphate used.(0.001)

PV=peroxide value (meq/kg)

$$PV = (S-B) * N * 1000 / SW$$

### 2.5 GRAPHICAL ANALYSIS

The experimental data obtain using the previous procedures were analyzed by plotting Graph and developing Models for various observations for different time.

### 2.6 STATISTICAL ANALYSIS

The experimental data obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations: like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2$ , where  $y$  is the response,  $x_i$  is the uncoded independent variable (factor), and  $\beta_0, \beta_i, \beta_{ii}$  are intercept, linear and quadratic respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variable which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs.

## 3 RESULT AND DISCUSSION

3.1 Below is the graphical trend of peroxide value with respect to time of heating and the drawn trend line by M S-Excel and the equation developed with it R-Square. (data reference 19)

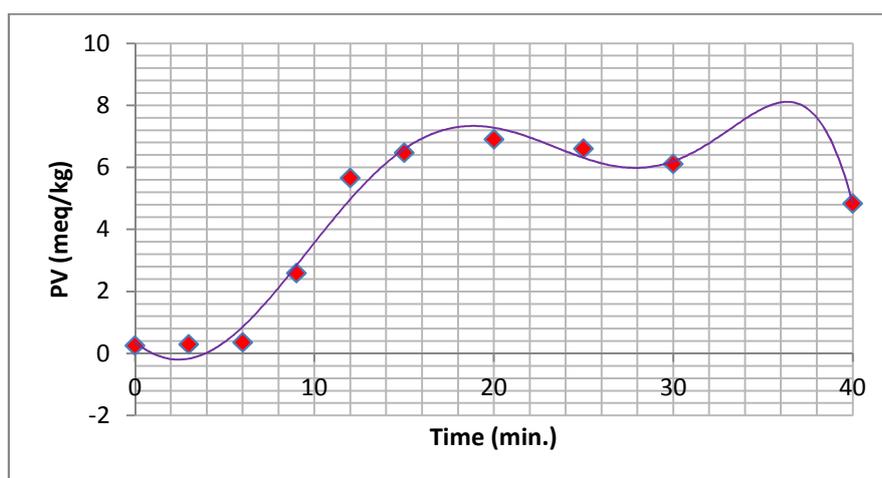


Fig 1. Graph plotted on M S Excel peroxide value Vs Induction Time during Microwave cooking of oil.

Model 1 equation:

$$y = -2E-07x^6 + 2E-05x^5 - 0.0006x^4 + 0.003x^3 + 0.0889x^2 - 0.4552x + 0.361$$

$$R^2 = 0.9826$$

where x is time of induction of oil in minutes, and y is the peroxide value at specified induction time

**3.2 The results from Statistical Analysis using Expert Design Software we get**

*Table 2. Model fit Summary*

Model Summary Statistics						
Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	2.12	0.5014	0.4391	0.0117	71.47	
<u>Quadratic</u>	<u>1.12</u>	<u>0.8775</u>	<u>0.8425</u>	<u>0.7492</u>	<u>18.14</u>	<u>Suggested</u>
Cubic	1.21	0.8791	0.8187	-1.2737	164.43	
<u>Quartic</u>	<u>0.77</u>	<u>0.9587</u>	<u>0.9257</u>	<u>-6.1478</u>	<u>516.91</u>	<u>Suggested</u>
Fifth	0.62	0.9787	0.9520	-3.9871	360.65	
Sixth	0.65	0.9826	0.9479	-669.0200	48453.88	

*\*Model Summary Statistics\*:* Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

*Table 3. showing P-Value for fit summary*

Summary (detailed tables shown below)					
Source	Sequential p-value	Lack of Fit p-value	Adjusted R-Squared	Predicted R-Squared	
Linear	0.0219		0.4391	0.0117	
<u>Quadratic</u>	<u>0.0024</u>		<u>0.8425</u>	<u>0.7492</u>	<u>Suggested</u>
Cubic	0.7864		0.8187	-1.2737	
<u>Quartic</u>	<u>0.0267</u>		<u>0.9257</u>	<u>-6.1478</u>	<u>Suggested</u>
Fifth	0.1250		0.9520	-3.9871	
Sixth	0.4695		0.9479	-669.0200	

*Table 4. Showing Sequential Model Sum of Square*

Sequential Model Sum of Squares [Type I]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	160.44	1	160.44			
Linear vs Mean	36.26	1	36.26	8.05	0.0219	
<u>Quadratic vs L</u>	<u>27.20</u>	<u>1</u>	<u>27.20</u>	<u>21.49</u>	<u>0.0024</u>	<u>Suggested</u>
Cubic vs Quad	0.12	1	0.12	0.080	0.7864	
<u>Quartic vs Cub</u>	<u>5.76</u>	<u>1</u>	<u>5.76</u>	<u>9.64</u>	<u>0.0267</u>	<u>Suggested</u>
Fifth vs Quartic	1.44	1	1.44	3.75	0.1250	
Sixth vs Fifth	0.29	1	0.29	0.68	0.4695	
Residual	1.26	3	0.42			
Total	232.76	10	23.28			

*\*Sequential Model Sum of Squares [Type I]\*:* Select the highest order polynomial where the additional terms are significant and the model is not aliased.

Table 5. showing ANOVA for Response surface Fifth Model

Response	1	PV				
ANOVA for Response Surface Quadratic model						
Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	63.46	2	31.73	25.07	0.0006	significant
A-Time	28.94	1	28.94	22.87	0.0020	
A <sup>2</sup>	27.20	1	27.20	21.49	0.0024	
Residual	8.86	7	1.27			
Cor Total	72.32	9				

The Model F-value of 25.07 implies the model is significant. There is only a 0.06% chance that an F-value this large could occur due to noise.

Table 6. ANOVA analysis table.

Std. Dev.	1.12	R-Squared	0.8775
Mean	4.01	Adj R-Squared	0.8425
C.V. %	28.08	Pred R-Square	0.7492
PRESS	18.14	Adeq Precisor	12.732

The "Pred R-Squared" of 0.7492 is in reasonable agreement with the "Adj R-Squared" of 0.8425; i.e. the difference is less than 0.2.

Model 2 Fifth degree equation from the Design Expert Software 8.0

**Final Equation in Terms of Actual Factors:**

$$\begin{aligned}
 PV = & \\
 & -0.99221 \\
 & +0.60056 * \text{Time} \\
 & -0.011471 * \text{Time}^2
 \end{aligned}$$

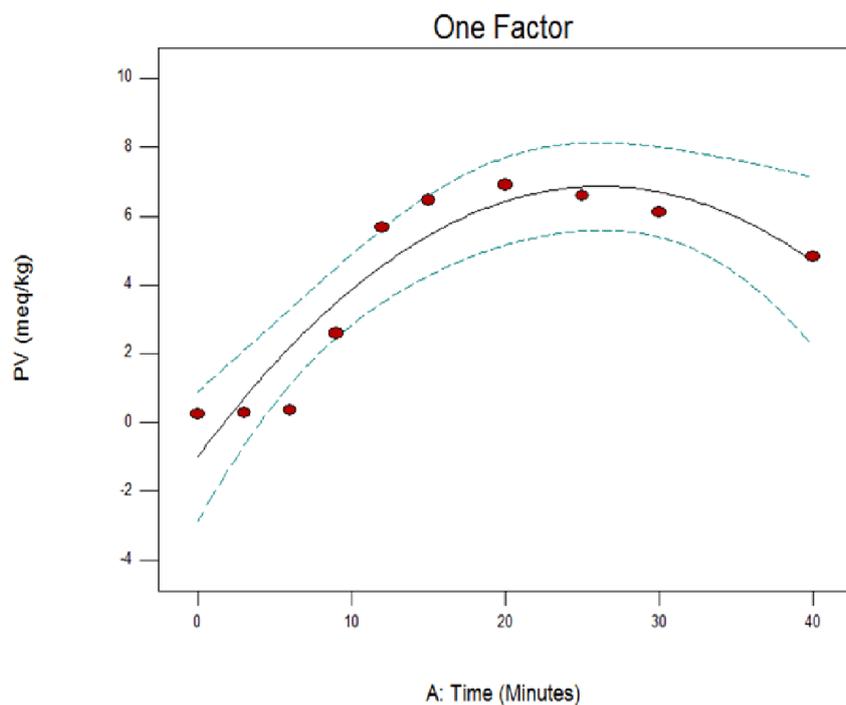


Fig 2. Graph Peroxide value Vs Induction Time by Software for Quadratic Model

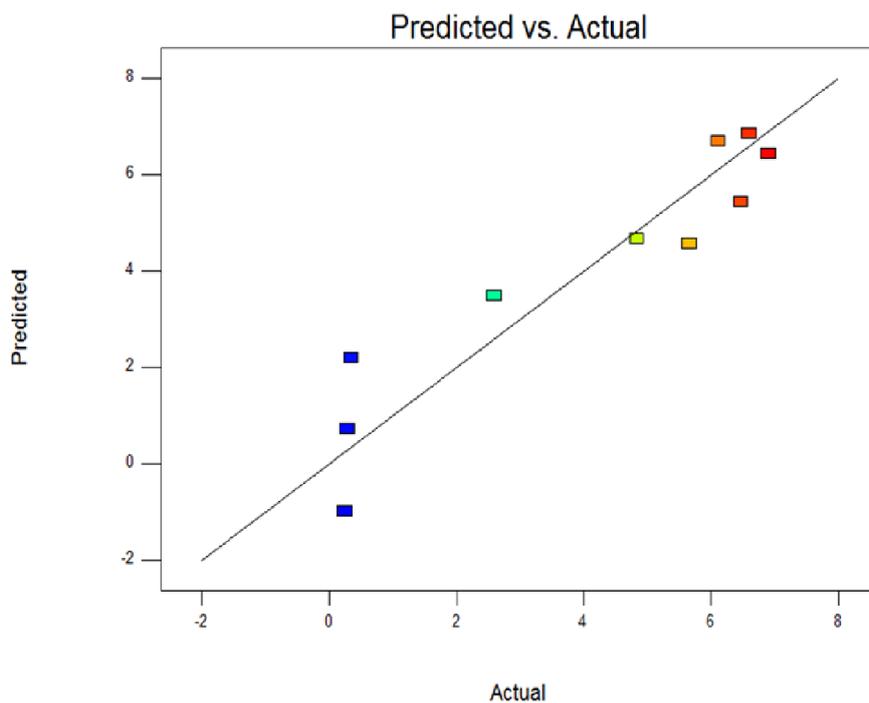


Fig 3. Graph Predicted Vs Actual values of Oxidation for model 2

Table 7. ANOVA for Response Surface Quadratic model

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	97.93	2	48.96	18.87	0.0015	significant
A-Time	30.15	1	30.15	11.62	0.0113	
A <sup>2</sup>	56.90	1	56.90	21.93	0.0023	
Residual	18.16	7	2.59			
Cor Total	116.09	9				

The Model F-value of 18.87 implies the model is significant. There is only a 0.15% chance that an F-value this large could occur due to noise.

Table 8. ANOVA Analysis Table for Quadratic Model

Std. Dev.	1.61	R-Squared	0.8436
Mean	6.25	Adj R-Squared	0.7989
C.V. %	25.79	Pred R-Square	0.3600
PRESS	74.29	Adeq Precisor	11.152

The "Pred R-Squared" of 0.3600 is not as close to the "Adj R-Squared" of 0.7989 as one might normally expect; i.e. the difference is more than 0.2. This may indicate a large block effect

## Model 2 Quadratic Equation by Design Expert Software 8.0

## Final Equation in Terms of Actual Factors:

$$\begin{aligned}
 PV = & \\
 & -0.017681 \\
 & +0.80836 * \text{Time} \\
 & -0.016592 * \text{Time}^2
 \end{aligned}$$

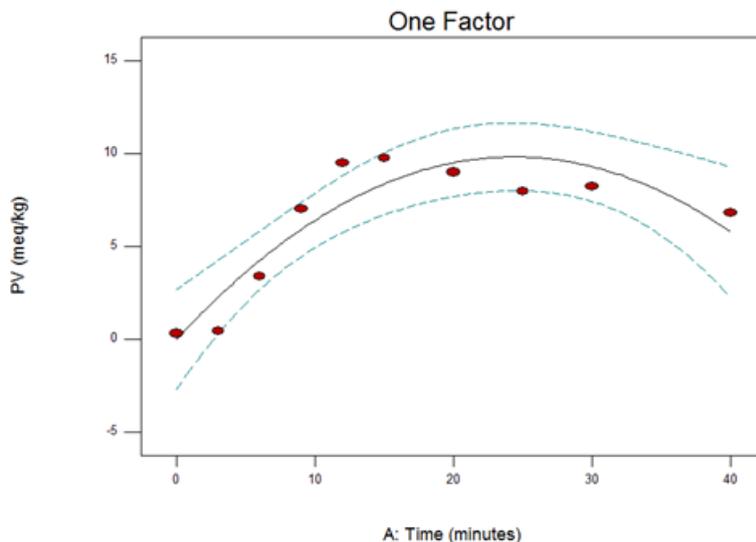


Fig 4. Graph Peroxide value Vs Induction Time by Software for Quadratic Model

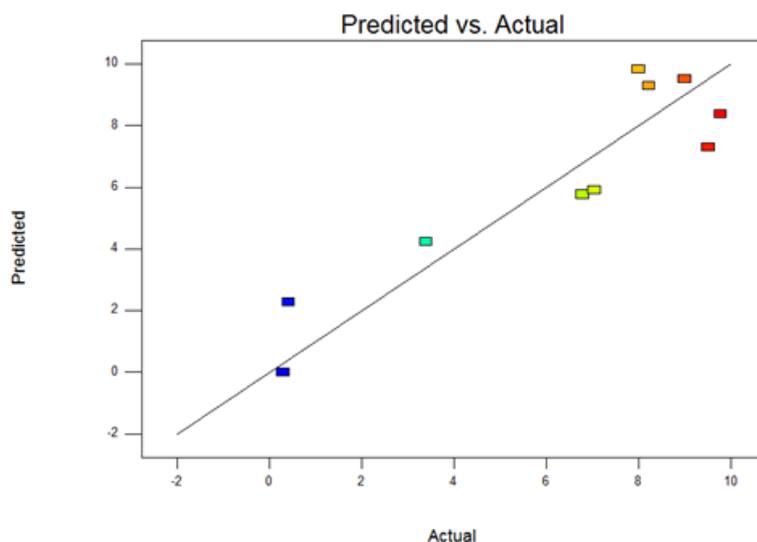


Fig 5. Graph Predicted Vs Actual values of Oxidation for model 2

#### 4 CONCLUSION

We can see there are three equations or model developed which are significant as there  $R^2 \geq 0.8775$  for relationship between peroxide value and Microwave heating time duration.

#### ACKNOWLEDGEMENT

We are appreciative of the SHIATS University for its continuous support in the development of important technologies for the future use. The effort of higher authorities to promote the technologies has been very valuable in the promotion of new technologies. A special thanks goes to the dean and head of department for believing in our dream to develop new technologies. Many people have contributed either directly or indirectly to make this work a reality.

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## AUTHOR'S BIOGRAPHY

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



## CORRESPONDENCE AUTHOR'S ADDRESS

Ravi Shankar

Duplex no. 40, Dev Villa, Post Office Road, Mango, Jamshedpur, Jharkhand-831001

## Mathematical Modeling of Degree of Thermal Oxidation of Lard as a Function of Induction Time at Fixed Induced Power During Microwave Heating

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This is about relating the thermal induction time range from 0-40 minutes for Lard of definite composition with the change in the thermal oxidation by the models developed by using M S Excel and Statistical Software, Design Expert Software 8.0 with there  $R^2$ . And through analysis of prepared model data with their plotted graph.

**KEYWORDS:** Thermal Oxidation, Peroxide value, Design Expert Software 8.0, M S Excel, Microwave Oven, Modeling.

### 1 INTRODUCTION

Thermal oxidation of edible oil or fat is an important determination of the quality of edible oil. During processing of food stuffs involving the use of edible oils such as blended oil as a heat transfer medium, the oil owing to high temperature undergoes thermal oxidation over a period of time. Due to the thermal oxidation of edible oils, they become unfit for further use after a period of time. Hence proper control of processing condition is a desirable requirement in order to delay the onset of thermal oxidation of edible oil or fat.

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system. Mathematical models in the field of oxidation of edible Fat can enable the determination of time of cook of edible Fat which would lead to the least amount of oxidation of edible oil during processing using edible oils as a heating medium.

Mathematical models can enable the optimization of frying time at fixed power to reduce the rancidity of frying fat. In light of above considerations the study was conducted in order to attain the following objective

- 1) To determine the relationship of the Thermal oxidation as function of Induction time of the Lard at fixed power during microwave cooking

Heating is an important part of many food processing operations. Many desirable changes, as well as undesirable reactions, occur in fat when they are heated at elevated temperature. However, during heating, vegetable oils are very sensitive and susceptible to quality changes, caused by chemical instability, that are dependent on both chemical composition and environmental factors. Lipid oxidation is one of the major deleterious reactions during heating that markedly affects the quality of lard. This chemical reaction is of primary concern to many researchers in the field of fats and oils. The extensive studies on lipid oxidation have spurred a vast array of findings in the field of fats and oils processing. Today, it is well known that this deleterious reaction leads to the formation of various oxidation products, which may result in the oil and fat products becoming unfit for human consumption. Compositional and/or environmental effects on lipid oxidation can be expressed by a mathematical relationship. However, this relationship applies only to several simple food

systems and reactions. More often, oxidative reactions of lard are more complex and unique in their behavior, and the appropriate model must be derived individually for each product and oil system. Temperature is one of the main environmental factors that influence the rate of quality loss. The dependence on temperature of most reactions in foods can be expressed more precisely by the Arrhenius model.

## 2 MATERIALS AND METHODS

### 2.1 EDIBLE LARD COMPOSITION.

**Table 1.** <sup>19</sup> *Composition of Lard used.*

Component	Pork lard
<b>Main fatty acids (% of peak area)</b>	
Palmitic	28
Stearic	11
C <sub>20</sub> -C <sub>22</sub> saturated	1
Monoenoic	52
Dienoic	6
Trienoic	trace
Eicosenoic	—
Trans-unsaturated	trace
Peroxide value (meq/kg)	1.2
Acid value (mg/g)	0.6
Conjugated dienes (% m/m)	trace
Polar compounds (% m/m)	1.2
<b>Tocopherols (mg/kg)</b>	
Tocopherol $\alpha$	5
Tocopherol $\beta+\gamma$	—
Tocopherol $\delta$	—
Total tocopherols	5

### 2.2 PREPARATION OF SAMPLES (REFERENCE [19])

### 2.3 SAMPLE COLLECTION (REFERENCE [19])

\*Assumptions

- Surface area exposed to atmosphere is constant or same.
- No mixing or agitation.

### 2.4 MEASUREMENT OF OXIDATION

#### 2.4.1 PEROXIDE VALUE (PV) ANALYTICAL METHOD.

##### 2.4.1.1 PURPOSE AND SCOPE

This method describes the determination of peroxides values for vegetable oils and fats. The peroxide value is a parameter specifying the content of oxygen as peroxide, especially hydro peroxides in a substance. The peroxide value is a measure of the oxidation present.

#### 2.4.1.2 PRINCIPLE

The sample treated in the solution with a mixture of acetic acid and a suitable organic solvent and then with a solution of potassium iodide. The liberated iodine is titrated with a standard solution of sodium thiosulphate.

Peroxides and similar products which oxidize potassium iodide under the conditions of the test will contribute to the peroxide value. Variations in procedure may affect the results. Peroxide values are expressed either in milliequivalents of peroxide/kg or millimoles of peroxide/l.

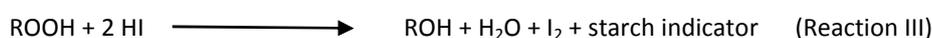
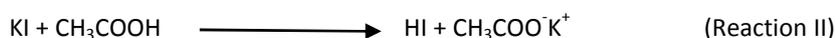
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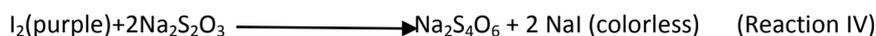
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Generation of iodine:



Titration step:



Reaction of peroxides of the structures R-O-O-R' and

R-CH-O-O-CH-R' follows an analogous pathway. Whilst cyclic peroxides do not react quantitatively under the conditions described here.

Alternatively, the ion reaction is of more of general applicability:



#### 2.4.1.4 PROCEDURE

- i) Approx. 3.0g of the sample was transferred, accurately weighed, into a 250 ml conical flask.
- ii) 25 ml of the appropriate solvent mixture (glacial acetic acid: chloroform, 1:2) and 1 ml saturated potassium iodide solution freshly prepared was added.
- iii) Was Allowed to react for 60 sec. and shaking thoroughly during this period. Then 35 ml of distilled water was added.
- iv) Then was titrated with 0.001 N sodium thiosulphate solution using 0.5 ml 1%starch solution as indicator.
- v) During the titration shaken until the blue color disappeared.
- vi) Blank titration was carried under the same conditions.

#### 2.4.1.5 CALCULATIONS

S=titration of sample.

B=titration of blank.

SW=weight of sample taken.(gm)

N=normality of sodium thiosulphate used.(0.001)

PV=peroxide value (meq/kg)

$$PV = (S-B)*N*1000/SW$$

## 2.5 GRAPHICAL ANALYSIS

The experimental data obtain using the previous procedures were analyzed by plotting Graph and developing Models for various observations for different time.

## 2.6 STATISTICAL ANALYSIS

The experimental data obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations: like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2$ , where  $y$  is the response,  $x_i$  is the uncoded independent variable (factor), and  $\beta_0$ ,  $\beta_i$ ,  $\beta_{ii}$  are intercept, linear and quadratic respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variable which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs.

## 3 RESULT AND DISCUSSION

3.1 Below is the graphical trend of peroxide value with respect to time of heating and the drawn trend line by M S-Excel and the equation developed with it R-Square. (data reference 19)

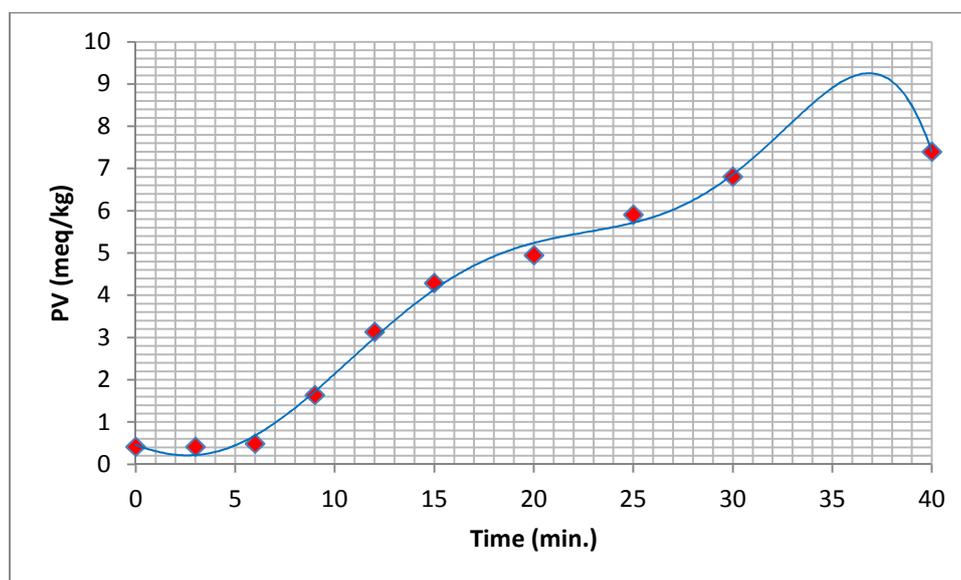


Fig 1. Graph plotted on M S Excel peroxide value Vs Induction Time during Microwave cooking of Lard.

Model 1 equation:

$$y = -1E-07x^6 + 1E-05x^5 - 0.0005x^4 + 0.0047x^3 + 0.0206x^2 - 0.1726x + 0.4587$$

$$R^2 = 0.9962$$

where  $x$  is time of induction of oil in minutes, and  $y$  is the peroxide value at specified induction time

3.2 The results from Statistical Analysis using Expert Design Software we get

Table 2. Model fit Summary

Summary (detailed tables shown below)

Source	Sequential p-value	Lack of Fit p-value	Adjusted R-Squared	Predicted R-Squared	
Linear	< 0.0001		0.9246	0.8624	
<u>Quadratic</u>	<u>0.0443</u>		<u>0.9535</u>	<u>0.8840</u>	<u>Suggested</u>
Cubic	0.1181		0.9651	0.7004	
Quartic	0.0688		0.9798	-1.1211	
Fifth	0.1174		0.9873	-1.7514	
Sixth	0.3145		0.9886	-230.8472	

Table 3. showing P-Value for fit summary

Sequential Model Sum of Squares [Type I]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	125.39	1	125.39			
Linear vs Mear	61.92	1	61.92	111.29	< 0.0001	
<u>Quadratic vs L</u>	<u>2.05</u>	<u>1</u>	<u>2.05</u>	<u>5.99</u>	<u>0.0443</u>	<u>Suggested</u>
Cubic vs Quad	0.86	1	0.86	3.33	0.1181	
Quartic vs Cub	0.80	1	0.80	5.34	0.0688	
Fifth vs Quartic	0.37	1	0.37	3.96	0.1174	
Sixth vs Fifth	0.12	1	0.12	1.45	0.3145	
Residual	0.25	3	0.084			
Total	191.76	10	19.18			

Table 4. Showing Sequential Model Sum of Square

Sequential Model Sum of Squares [Type I]

Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Mean vs Total	125.39	1	125.39			
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<u>Quadratic vs L</u>	<u>2.05</u>	<u>1</u>	<u>2.05</u>	<u>5.99</u>	<u>0.0443</u>	<u>Suggested</u>
Cubic vs Quad	0.86	1	0.86	3.33	0.1181	
Quartic vs Cub	0.80	1	0.80	5.34	0.0688	
Fifth vs Quartic	0.37	1	0.37	3.96	0.1174	
Sixth vs Fifth	0.12	1	0.12	1.45	0.3145	
Residual	0.25	3	0.084			
Total	191.76	10	19.18			

Table 5. Model Summary Statistics

Model Summary Statistics						
Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	0.75	0.9329	0.9246	0.8624	9.13	
<u>Quadratic</u>	<u>0.59</u>	<u>0.9639</u>	<u>0.9535</u>	<u>0.8840</u>	<u>7.70</u>	<u>Suggested</u>
Cubic	0.51	0.9767	0.9651	0.7004	19.88	
Quartic	0.39	0.9888	0.9798	-1.1211	140.79	
Fifth	0.31	0.9944	0.9873	-1.7514	182.63	
Sixth	0.29	0.9962	0.9886	-230.8472	15388.84	

"Model Summary Statistics": Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

Table 6. showing ANOVA for Response surface Fifth Model

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	63.98	2	31.99	93.34	< 0.0001	significant
A-Time	58.54	1	58.54	170.82	< 0.0001	
A <sup>2</sup>	2.05	1	2.05	5.99	0.0443	
Residual	2.40	7	0.34			
Cor Total	66.37	9				

The Model F-value of 93.34 implies the model is significant. There is only a 0.01% chance that an F-value this large could occur due to noise.

Table 7. ANOVA analysis table.

Std. Dev.	0.59	R-Squared	0.9639
Mean	3.54	Adj R-Squared	0.9535
C.V. %	16.53	Pred R-Square	0.8840
PRESS	7.70	Adeq Precisor	25.148

The "Pred R-Squared" of 0.8840 is in reasonable agreement with the "Adj R-Squared" of 0.9535; i.e. the difference is less than 0.2.

Model 2 Fifth degree equation from the Design Expert Software 8.0

Final Equation in Terms of Actual Factors:

$$PV = -0.43436 + 0.32764 * \text{Time} - 3.15126E-003 * \text{Time}^2$$

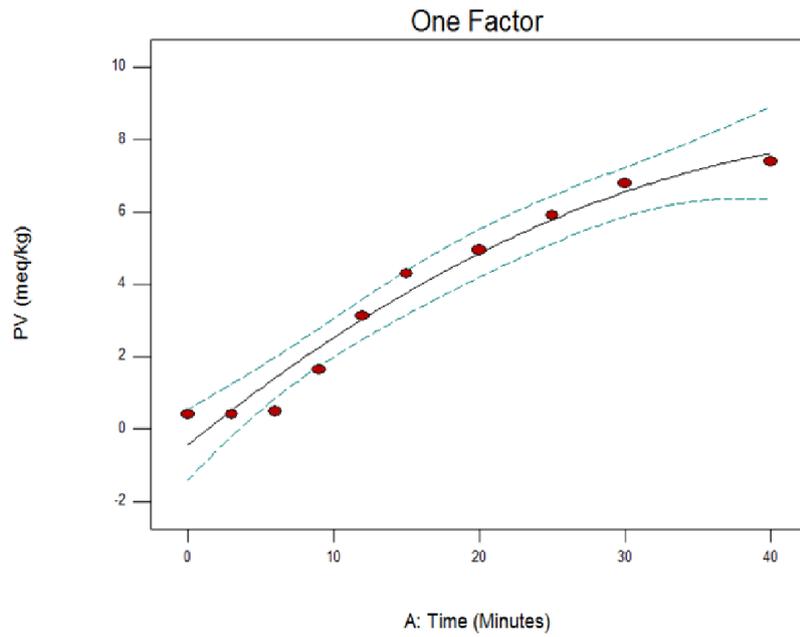


Fig 2. Graph Peroxide value Vs Induction Time by Software for Quadratic Model

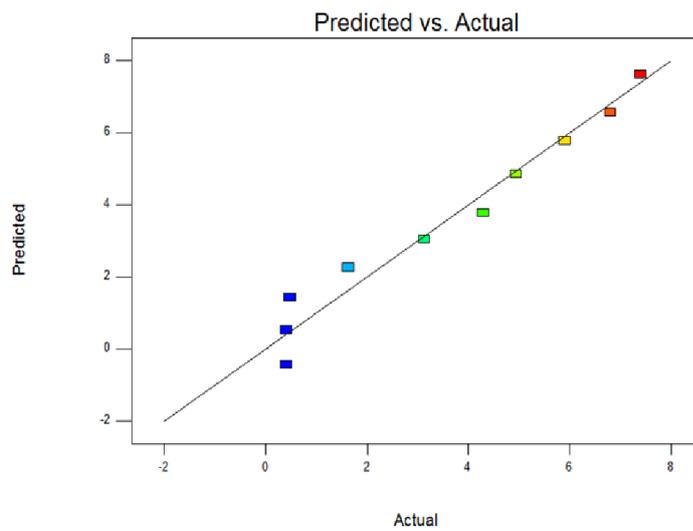


Fig 3. Graph Predicted Vs Actual values of Oxidation for model 2

## 4 CONCLUSION

We can see there are two equations or models developed which are significant as there  $R^2 \geq 0.9639$  for relationship between peroxide value and Microwave heating time duration.

## ACKNOWLEDGEMENT

We are appreciative of the SHIATS University for its continuous support in the development of important technologies for the future use. The effort of higher authorities to promote the technologies has been very valuable in the promotion of new technologies. A special thanks goes to the dean and head of department for believing in our dream to develop new technologies. Many people have contributed either directly or indirectly to make this work a reality.

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## AUTHOR'S BIOGRAPHY

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.





## Mathematical Modeling of Degree of Thermal Oxidation of Edible Oil (Virginia Pea nut) as a Function of Induction Time at Fixed Induced Power During Microwave Heating

*Ravi Shankar*

Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology,  
Sam HigginBottom Institute of Agriculture, Technology and Sciences-Deemed University,  
P.O Naini, Allahabad, U.P-211007, India

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**ABSTRACT:** This is about relating the thermal induction time range from 0-40 minutes for Verginia Peanut oil (refined) of definite composition with the change in the thermal oxidation by the models developed by using M S Excel and Statistical Software, Design Expert Software 8.0 with there  $R^2$ . And through analysis of prepared model data with their plotted graph.

**KEYWORDS:** Thermal Oxidation, Peroxide value, Design Expert Software 8.0, M S Excel, Microwave Oven, Modeling.

### 1 INTRODUCTION

Thermal oxidation of edible oil is an important determination of the quality of edible oil. During processing of food stuffs involving the use of edible oils such as blended oil as a heat transfer medium, the oil owing to high temperature undergoes thermal oxidation over a period of time. Due to the thermal oxidation of edible oils, they become unfit for further use after a period of time. Hence proper control of processing condition is a desirable requirement in order to delay the onset of thermal oxidation of edible oil.

Mathematical modeling is an effective way of representing a particular process. It can help us to understand and explore the relationship between the process parameters. Mathematical modeling can help to understand and quantitative behavior of a system. Mathematical models are useful representation of the complete system which is based on visualizations. Mathematical modeling is an important method of translating problems from real life systems to conformable and manageable mathematical expressions whose analytical consideration determines an insight and orientation for solving a problem and provides us with a technique for better development of the system. Mathematical models in the field of oxidation of edible oils can enable the determination of time of cook of edible oil which would lead to the least amount of oxidation of edible oil during processing using edible oils as a heating medium.

Mathematical models can enable the optimization of frying time at fixed power to reduce the rancidity of frying oils. In light of above considerations the study was conducted in order to attain the following objective

- 1) To determine the relationship of the Thermal oxidation as function of Induction time of the frying oil at fixed power during microwave cooking

Heating is an important part of many food processing operations. Many desirable changes, as well as undesirable reactions, occur in vegetable oils when they are heated at elevated temperature. However, during heating, vegetable oils are very sensitive and susceptible to quality changes, caused by chemical instability, that are dependent on both chemical composition and environmental factors. Lipid oxidation is one of the major deleterious reactions during heating that markedly affects the quality of vegetable oils. This chemical reaction is of primary concern to many researchers in the field of fats and oils. The extensive studies on lipid oxidation have spurred a vast array of findings in the field of fats and oils processing. Today, it is well known that this deleterious reaction leads to the formation of various oxidation products, which may result in the oil and fat products becoming unfit for human consumption. Compositional and/or environmental effects on lipid oxidation can be expressed by a mathematical relationship. However, this relationship applies only to several simple

food systems and reactions. More often, oxidative reactions of vegetable oils are more complex and unique in their behavior, and the appropriate model must be derived individually for each product and oil system. Temperature is one of the main environmental factors that influence the rate of quality loss. The dependence on temperature of most reactions in foods can be expressed more precisely by the Arrhenius model.

Shahidi and Spurvey (1996) stated that Autoxidation of oils and the decomposition of hydroperoxides increase as the temperature increases. Velasco and Dobarganes (2002) stated that the formation of autoxidation products during the induction period is slow at low temperature. The concentration of the hydroperoxides increases until the advanced stages of oxidation. Marquez-Ruiz *et al.* (1996) suggested that The content of polymerized compounds increases significantly at the end of the induction period of autoxidation. Yang and Min (1994); Rahmani and Saari Csallani (1998) suggested that temperature has little effect on oil oxidation due to the low activation energy of 0 to 6 kcal/mole. Sattar *et al.* (1976) stated that light is much more important than temperature in oil oxidation.

## 2 MATERIALS AND METHODS

### 2.1 EDIBLE VIRGINIA PEANUT OIL COMPOSITION.

*Table 1. <sup>19</sup>Composition of Refined Virginia peanut Oil used.*

Component	Oil Type
	Virginia peanut
<b>Main fatty acids (% of peak area)</b>	
Palmitic	12
Stearic	3
C <sub>20</sub> -C <sub>22</sub> saturated	5
Monoenoic	48
Dienoic	30
Trienoic	trace
Eicosenoic	1
Trans-unsaturated	0.8
Peroxide value (meq/kg)	1.5
Acid value (mg/g)	1.5
Conjugated dienes (% m/m)	2.1
Polar compounds (% m/m)	2.1
<b>Tocopherols (mg/kg)</b>	
Tocopherol $\alpha$	162
Tocopherol $\beta+\gamma$	134
Tocopherol $\delta$	6
Total tocopherols	303

### 2.2 PREPARATION OF SAMPLES (REFERENCE [19])

### 2.3 SAMPLE COLLECTION (REFERENCE [19])

\*Assumptions

- Surface area exposed to atmosphere is constant or same.
- No mixing or agitation.

## 2.4 MEASUREMENT OF OXIDATION

### 2.4.1 PEROXIDE VALUE (PV) ANALYTICAL METHOD.

#### 2.4.1.1 PURPOSE AND SCOPE

This method describes the determination of peroxides values for vegetable oils and fats. The peroxide value is a parameter specifying the content of oxygen as peroxide, especially hydro peroxides in a substance. The peroxide value is a measure of the oxidation present.

#### 2.4.1.2 PRINCIPLE

The sample treated in the solution with a mixture of acetic acid and a suitable organic solvent and then with a solution of potassium iodide. The liberated iodine is titrated with a standard solution of sodium thiosulphate.

Peroxides and similar products which oxidize potassium iodide under the conditions of the test will contribute to the peroxide value. Variations in procedure may affect the results. Peroxide values are expressed either in milliequivalents of peroxide/kg or millimoles of peroxide/l.

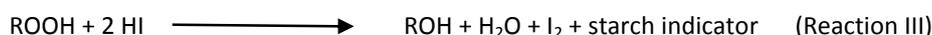
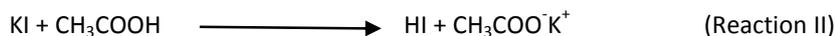
Reaction scheme:

The peroxide value is determined by measuring the iodine liberated from potassium iodide by a peroxide, using sodium thiosulphate solution as the titrant. In the presence of acetic acid, the reaction scheme for hydroperoxides is as follows.

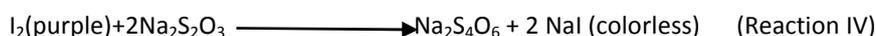
Generation of hydroperoxides:



Generation of iodine:



Titration step:



Reaction of peroxides of the structures R-O-O-R' and

R-CH-O-O-CH-R' follows an analogous pathway. Whilst cyclic peroxides do not react quantitatively under the conditions described here.

Alternatively, the ion reaction is of more of general applicability:



#### 2.4.1.4 PROCEDURE

- i) Approx. 3.0g of the sample was transferred, accurately weighed, into a 250 ml conical flask.
- ii) 25 ml of the appropriate solvent mixture (glacial acetic acid: chloroform, 1:2) and 1 ml saturated potassium iodide solution freshly prepared was added.
- iii) Was Allowed to react for 60 sec. and shaking thoroughly during this period. Then 35 ml of distilled water was added.
- iv) Then was titrated with 0.001 N sodium thiosulphate solution using 0.5 ml 1%starch solution as indicator.
- v) During the titration shaken until the blue color disappeared.
- vi) Blank titration was carried under the same conditions.

### 2.4.1.5 CALCULATIONS

S=titration of sample.

B=titration of blank.

SW=weight of sample taken.(gm)

N=normality of sodium thiosulphate used.(0.001)

PV=peroxide value (meq/kg)

$$PV = (S-B) * N * 1000 / SW$$

### 2.5 GRAPHICAL ANALYSIS

The experimental data obtain using the previous procedures were analyzed by plotting Graph and developing Models for various observations for different time.

### 2.6 STATISTICAL ANALYSIS

The experimental data obtain using the previous procedures were analyzed by the response surface regression procedure using the following higher-order polynomial equations: like,  $y = \beta_0 + \sum \beta_i x_i + \sum \beta_{ii} x_i^2$ , where  $y$  is the response,  $x_i$  is the uncoded independent variable (factor), and  $\beta_0, \beta_i, \beta_{ii}$  are intercept, linear and quadratic respectively. Design Expert software package 8.0 was used for regression analysis, analysis of variance (ANOVA) and developing of models of different forms by transformation (linear and of higher order) based on above mentioned principles of forming a functions. Confirmatory experiments were carried out to validate the equations using the combinations of independent variable which were not part of the original experimental design but were within the experimental region. Various models were compared for the best fit summary and there  $R^2$  values were compared to choose the best appropriated model for particular data design and selected runs.

## 3 RESULT AND DISCUSSION

3.1 Below is the graphical trend of peroxide value with respect to time of heating and the drawn trend line by M S-Excel and the equation developed with it R-Square. (data reference 19)

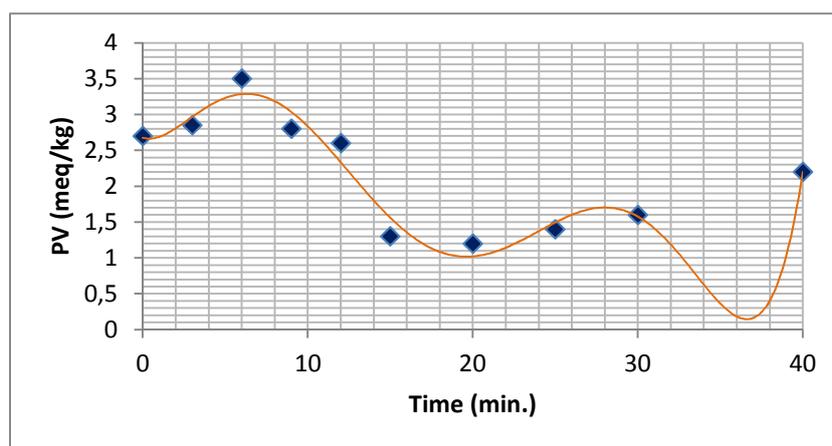


Fig 1. Graph plotted on M S Excel peroxide value Vs Induction Time during Microwave cooking of oil.

Model 1 equation:

$$y = 2E-07x^6 - 2E-05x^5 + 0.001x^4 - 0.0161x^3 + 0.0949x^2 - 0.0673x + 2.6756$$

$$R^2 = 0.9477$$

where x is time of induction of oil in minutes, and y is the peroxide value at specified induction time

### 3.2 The results from Statistical Analysis using Expert Design Software we get

*Table 2. Model fit Summary*

Model Summary Statistics						
Source	Std. Dev.	R-Squared	Adjusted R-Squared	Predicted R-Squared	PRESS	
Linear	0.68	0.3503	0.2691	-0.2082	6.88	
Quadratic	0.57	0.5977	0.4828	-0.0025	5.70	
Cubic	0.51	0.7224	0.5836	-5.2068	35.32	
<u>Quartic</u>	<u>0.34</u>	<u>0.8961</u>	<u>0.8129</u>	<u>-1.0933</u>	<u>11.91</u>	<u>Suggested</u>
Fifth	0.38	0.8963	0.7667	-149.9778	859.10	
Sixth	0.32	0.9477	0.8430	-534.4733	3046.98	

*"Model Summary Statistics":* Focus on the model maximizing the "Adjusted R-Squared" and the "Predicted R-Squared".

*Table 3. showing P-Value for fit summary*

Summary (detailed tables shown below)					
Source	Sequential p-value	Lack of Fit p-value	Adjusted R-Squared	Predicted R-Squared	
Linear	0.0219		0.4391	0.0117	
<u>Quadratic</u>	<u>0.0024</u>		<u>0.8425</u>	<u>0.7492</u>	<u>Suggested</u>
Cubic	0.7864		0.8187	-1.2737	
<u>Quartic</u>	<u>0.0267</u>		<u>0.9257</u>	<u>-6.1478</u>	<u>Suggested</u>
Fifth	0.1250		0.9520	-3.9871	
Sixth	0.4695		0.9479	-669.0200	

Table 4. Showing Sequential Model Sum of Square

Sequential Model Sum of Squares [Type I]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
<u>Mean vs Total</u>	<u>49.06</u>	<u>1</u>	<u>49.06</u>			<u>Suggested</u>
Linear vs Mean	1.99	1	1.99	4.31	0.0714	
Quadratic vs Linear	1.41	1	1.41	4.30	0.0767	
Cubic vs Quadratic	0.71	1	0.71	2.69	0.1518	
<u>Quartic vs Cubic</u>	<u>0.99</u>	<u>1</u>	<u>0.99</u>	<u>8.35</u>	<u>0.0342</u>	<u>Suggested</u>
Fifth vs Quartic	1.287E-003	1	1.287E-003	8.724E-003	0.9301	
Sixth vs Fifth	0.29	1	0.29	2.95	0.1846	
Residual	0.30	3	0.099			
Total	54.75	10	5.48			

Table 5. showing ANOVA for Response surface Fifth Model

Analysis of variance table [Partial sum of squares - Type III]						
Source	Sum of Squares	df	Mean Square	F Value	p-value Prob > F	
Model	5.10	4	1.27	10.78	0.0113	significant
A-Time	0.70	1	0.70	5.92	0.0591	
A <sup>2</sup>	1.52	1	1.52	12.87	0.0158	
A <sup>3</sup>	0.35	1	0.35	2.97	0.1454	
A <sup>4</sup>	0.99	1	0.99	8.35	0.0342	
Residual	0.59	5	0.12			
Cor Total	5.69	9				

The Model F-value of 10.78 implies the model is significant. There is only a 1.13% chance that an F-value this large could occur due to noise.

Table 6. ANOVA analysis table.

Std. Dev.	0.34	R-Squared	0.8961
Mean	2.22	Adj R-Squared	0.8129
C.V. %	15.53	Pred R-Square	-1.0933
PRESS	11.91	Adeq Precisor	8.383

A negative "Pred R-Squared" implies that the overall mean is a better predictor of your response than the current model.

Model 2 Fifth degree equation from the Design Expert Software 8.0

Final Equation in Terms of Actual Factors:

$$\begin{aligned} \text{PV} = & \\ & +2.58739 \\ & +0.34597 * \text{Time} \\ & -0.051677 * \text{Time}^2 \\ & +2.01506\text{E-}003 * \text{Time}^3 \\ & -2.36391\text{E-}005 * \text{Time}^4 \end{aligned}$$

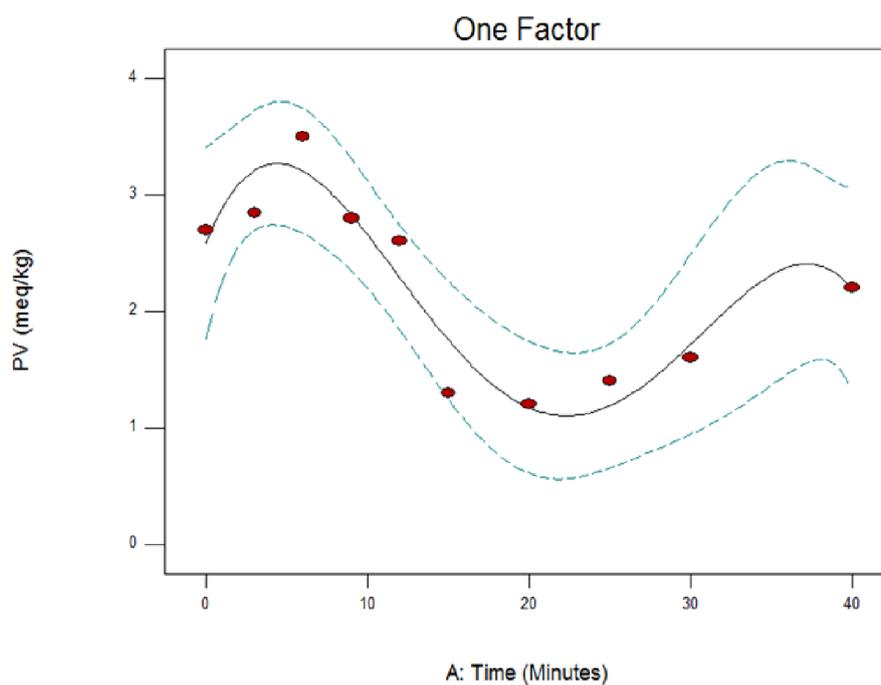


Fig 2. Graph Peroxide value Vs Induction Time by Software for Quadratic Model

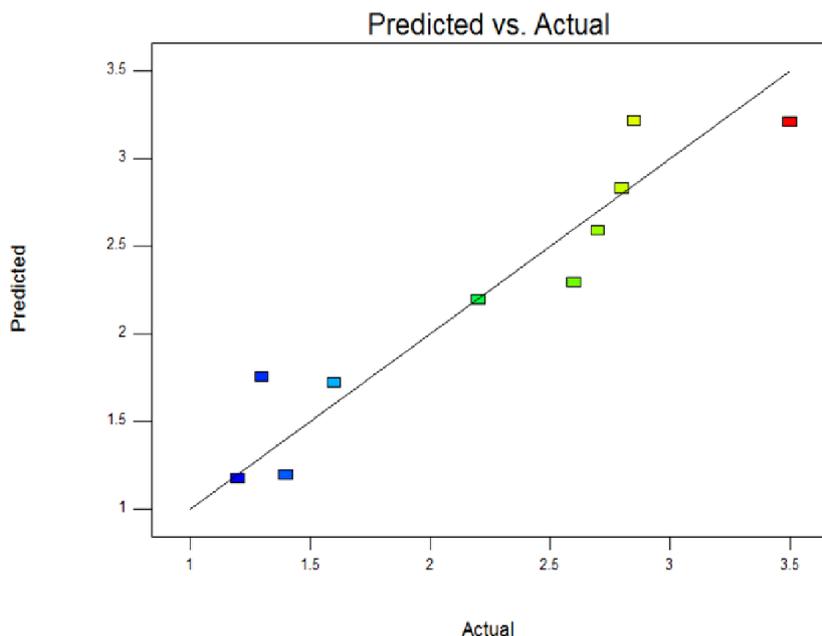


Fig 3. Graph Predicted Vs Actual values of Oxidation for model 2

#### 4 CONCLUSION

We can see there are three equations or model developed which are significant as there  $R^2 > 0.8961$  for relationship between peroxide value and Microwave heating time duration.

#### ACKNOWLEDGEMENT

We are appreciative of the SHIATS University for its continuous support in the development of important technologies for the future use. The effort of higher authorities to promote the technologies has been very valuable in the promotion of new technologies. A special thanks goes to the dean and head of department for believing in our dream to develop new technologies. Many people have contributed either directly or in indirectly to make this work a reality.

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#### AUTHOR'S BIOGRAPHY

RAVI SHANKAR- AMIMI, AMIAEI, AMIE, Pursuing M.Tech ( 4<sup>th</sup> sem) in Food Technology (Food Process Engineering), Department of Food Process Engineering, Vaugh School of Agriculture Engineering and Technology, SHIATS-Deemed University, P.O-Naini, Allahabad, U.P-211007, India. B.E in Food Technology, SLIET, Sangrur, (P.T.U) Punjab, India.



#### CORRESPONDENCE AUTHOR'S ADDRESS

Ravi Shankar

Duplex no. 40, Dev Villa, Post Office Road, Mango, Jamshedpur, Jharkhand-831001

## Behavioral Hindrance to Rapid Uptake of Mobile Money Services

*Bonface Barasa Makokha<sup>1</sup>, Deepa Ramachandran<sup>2</sup>, and Dr.P.Karthikeya<sup>3</sup>*

<sup>1</sup>Lecturer,  
School of Science Engineering & Nursing  
Daystar University,  
Nairobi, Kenya

<sup>2</sup>Research Scholar,  
Anna University,  
Chennai, India

<sup>3</sup>Assistant Professor,  
School of Management Studies  
Kongu Engineering College  
Perundurai, India

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**ABSTRACT:** Indian Mobile Network Operators (MNO) are in preparation to launch a major scale up of the mobile money services (MMS) following the policy recommendations by the Mobile Money Association of India (MMAI) through the leadership of Dr. Nachiket Mor. This has led to drastic changes in mobile money service regulations, setting a level playing ground for the MNOs. Enabling regulations, well-developed mobile network, and a huge customer base is an opportunity for the Indian MMS to grow to the level of Mpesa in Kenya. However, research indicates that many mobile money launches rarely meet the set targets. They project their growth based on the existing mobile phone subscribers and on the Mpesa's strategy in Kenya. This leads to dismal performance in the first twelve months. To mitigate the potential investment losses, management team of the MNOs need to understand the factors that may hinder rapid uptake of mobile money services. This paper presents the findings of a survey on behavior influence on usage and acceptance of mobile money services both in India and in Kenya.

**KEYWORDS:** Mpesa, Mobile Money Service, Mobile Network Operator, India Mobile Money Association, Technology acceptance

### 1 BACKGROUND

#### 1.1 MOBILE MONEY

This is the use of information and communication technologies (ICTs) to offer financial services to clients who would otherwise not be reached by the traditional branch-based financial services [10]. E-wallet is an example of Mobile Money Service (MMS) used to make peer-to-peer transfers and receive salaries. Some of the characteristics of a mobile money services includes transaction on an existing mobile network through Mobile Money Agents (MMA). Customers use an interface of basic mobile handsets.

## 1.2 MOBILE MONEY IN THE DEVELOPING COUNTRIES

Mobile money creates important changes in the lives of the poor. Relying solely on cash keeps many people excluded from the formal economy. Mobile money brings convenience to the doors of the poor since it is safe and readily available compared to cash [8],[9]. In developing countries like Kenya and Tanzania where Mobile Money is a success, the bottom of the pyramid feel included in national financial policy [6]. Apart from reducing dependency on cash, MMS has also opened an avenue for companies and institution to provide other vital financial services like the M-shwari, a savings and loan facility run on Mpesa platform in Kenya [8],[9].

Other countries with similar successful stories include Madagascar and Uganda [6]. In their survey, [8][9] indicates that mobile money accounts are twice more than the traditional bank accounts in these countries. In Kenya, 18 million people have Mpesa accounts whereas only seven million Kenyans have bank accounts, and two billion dollars is processed through Mpesa accounts every month [8],[9],[19]. India has advanced Mobile Networks and developmental similarities to Africa, which can be harnessed to open up MMS [18]. This would help trigger growth in the financial sector.

## 1.3 ENABLING REGULATION FOR MOBILE MONEY

All of the MMS in about 85 countries in the world thrive on enabling legislation, which allow non-bank businesses to run Mobile Money [10]. Some of these countries include Brazil, Kenya, Burundi, Zambia, Peru, Madagascar, Zimbabwe, Malaysia, Democratic Republic of Congo, Fiji, Uganda, Rwanda, amongst others [17]. However, in India the limiting factor is the regulatory barrier [16] causing masses at the base of the pyramid to depend on the cash.

## 1.4 NEW QUEST FOR MOBILE MONEY TRANSFER

In 2013, the Mobile Money Association of India (MMAI) submitted a recommendation paper to the Reserve Bank of India (RBI) Committee [7], providing evidence on the benefits of mobile money services. The proposal included regulatory reforms to provide a level playing ground and an enabling environment for mobile money deployments [18].

This resulted in the formation of a Committee on Comprehensive Financial Services for Small Businesses and Low-Income Households [7],[18]. The Reserve Bank of India (RBI) appointed Dr. Nachiket Mor as its chair [7] with a mandate to draw a clear, realistic and attainable road map for financial inclusion of the masses, and to review the current policies and approaches in order to eliminate hindrances to “financial inclusion and financial deepening” [4], p.131. The work of the Committee resulted in far-reaching effects especially where regulatory policy reforms are concerned.

## 1.5 EXCITEMENT OF MOBILE NETWORK OPERATORS

Plans are under way to invest heavily in the mobile money services following the proposal to eliminate policy barriers. Most Mobile Network Operators are expanding the existing infrastructure expecting massive and exponential growth in Mobile money customers. This assumption is based on the fact that Mpesa development in Kenya has been exponential yet Kenya does not have a well-developed mobile network compared to India [8],[18],[19].

Research indicates that many mobile money launches rarely meet the targets as set by the ambitious management team [5]. Strategic management teams tend to tailor their growth plan based on the Mpesa’s strategy in Kenya [13],[19] ignoring the behavioural differences between the two countries. This leads to dismal performance of mobile financial service in their first twelve months [15].

This research empirically determines factors that influence mobile money uptake in India in comparison with Kenya. The findings will enable the Mobile Network operators in India make informed choice on mobile money service scale up or adoption [18].

## 2 MATERIAL AND METHODS

The research was hinged to several theories as presented in the conceptual framework.

### 2.1 Conceptual Framework

#### a) Acceptance of Technology

User acceptance is the verifiable readiness by users to adopt technology for the correct purpose [30]. Lack of user acceptance is a major barrier to the success of innovation [30],[19]. Acceptance is the pivotal factor in shaping the future of any innovation. It is equally important to practitioners as it is for researchers to understand the reasons for accepting or rejecting innovation in information technology by a group of people [30]. This helps to determine better methods for “designing, evaluating, and predicting how users will respond” to the new technology [30], p195. For Mobile Money Services, acceptance level must be high for it to be a profitable venture for the MNOs.

**b) Theory of Reasoned Action (TRA)**

Theory of reasoned Action (TRA) aims to predict, explain, and influence human behaviour [20]. TRA is based on the following variables: Attitude towards the behaviour, intention, and subjective norms [21]. When looking at people, one needs to evaluate the degree to which performance of behaviour is positively or negatively valued [22]. The value on a behaviour results either in rejection or in acceptance of a product or service.

**c) Technology Acceptance Model (TAM)**

TAM is an extension of TRA model. It looks at the Perceived Usefulness (PU) and perceived ease of use (PEOU) [23] PU is the measure of the level of beliefs as to how useful a particular system is to one’s performance at work, whereas the PEOU deals with how a person feels that using the system requires no effort [24]. Mobile money service must be useful and requiring no effort when using it. The limitation of this model is that it provides limited guidance about how to “influence usage through design and implementation and the type of respondents” [24, p.720].

**d) Theory of Planned Behaviour (TPB)**

Theory of Planned Behaviour (TPB) addresses the limitations of the TRA model. TPB model incorporates the construct of perceived behavioral control (PBC) which influences both intention and behaviour [25]. It converts behavioural intentions into actions [25]. For example if there are intentions to use MMS, they result in actions.

**e) Innovation Diffusion Theory (IDT)**

In this model, an innovation is communicated through specified channels repeatedly among people of the same social beliefs [26]. Four elements of diffusion include Innovation, channels of communication, time frame and social setting [27]. The IDT theory empirically or otherwise does not explain how attitude evolves into either acceptance or rejection and how the innovations shape into this process [26], [25]

**f) Decomposed Theory of Planned Behaviour (DTPB)**

Decomposed theory of planned behaviour borrows from the theory of planned behaviour (TPB) and from innovation diffusion theory [25]. DTPB theory states that “attitude, subjective norm and perceived behavioural control” influences whether one will use technology or not [24]. The theory allows the decomposing of attitudes and control beliefs into several dimensions with the aim of arriving at a clear behavioural explanation. Clear understanding of the attitudes and beliefs of a group helps in knowing the trust level, hence determining the success of MMS. From TAM and TRA models’ perspective, trust is believed to have a positive effect on perceived usefulness, whereas the perceived ease of use has a positive influence on trust [25]

Trust is the antecedent of attitude, perceived behavioural control, and subjective norm. It increases the confidentiality of a business relationship and determines the quality of transaction between buyers and sellers [27]. Mutual trust and mutual influence between users and the technology innovation are highly correlated to each other [25]. The success of the MMS in India depends on the trust people have developed.

**2.1 RESEARCH MODEL**

TAM and DTPB states that the understandings of technology and trust issues are critical in determining behavioural intention to use MMS technology. An extension of the TAM model with DTPB would be a better way to understand the acceptance behaviour towards MMS and this would provide precise explanation that can be used to examine the problem and effectively improve usage and promote collaboration among the professionals.

The combination of the decomposed TPB model and the TAM model results in a model is that is taken as the theoretical basis for determining and elucidating factors that affect MMS technology uptake by the construction professionals in Qatar. According to DTPB model, intention to perform behaviour determines the frequency of the behaviour [24],[25],[26],[27]. The research model focuses on the behaviour towards the MMS technology. From the DTPB models, the research suggests to

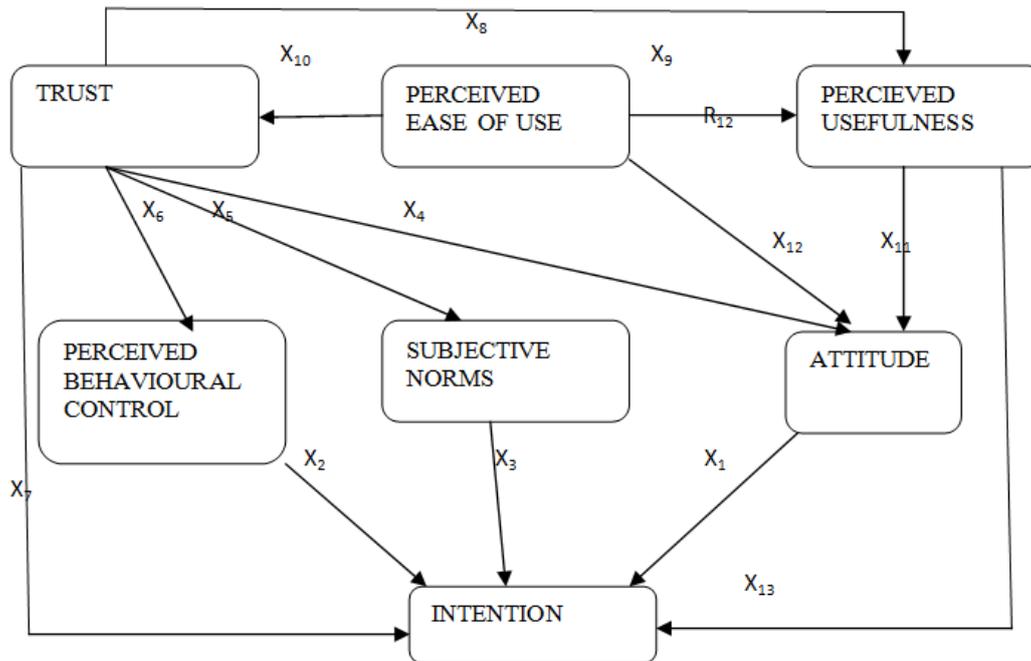
look at the behaviour from its four predicting factors: attitude toward the behaviour, subject norm, perceived behavioural control (PBC), and trust.

**2.2 RESEARCH QUESTIONS**

The research questions are as follows:

1. What are the factors influencing adoption of Mobile money services by Indian and Kenyan customers?
2. What is the role of social influence in acceptance of the mobile money services?

Research model is as shown in figure 1.



**Fig. 1. Research Model**

**2.3 HYPOTHESES**

Hypotheses are constructed based on the research questions, the literature review, and conceptual framework. X1 to X13 represents hypotheses relating the behavioral constructs.

**3 METHODOLOGY**

**3.1 RESEARCH PURPOSE AND STRATEGY**

This research was descriptive and deductive with a quantitative approach. The main research strategy employed was survey, which answered the question what. Samples of target populations in the two countries were done.

The population of interest was dwellers in Nairobi, Kenya and the dwellers in Chennai India. Being interested in the concept of intention, the respondents were those with mobile handsets, but without or with little mobile money transaction experienced. The sampling frame included rural, low and high-class dwellers both in Nairobi, Kenya and in Chennai India. The Survey took place between the months of January to March 2014

**3.2 SAMPLING TECHNIQUE**

The appropriate technique to help find barriers to MMS adoption was taken as the probability-sampling method.

### 3.3 MEASUREMENT OF CONSTRUCTS

Appropriate research constructs based on the extended literature review was developed. The following table1 presents constructs and their corresponding measurement used in the questionnaires.

*Table 1: Construct Definition*

Construct	Definition
Attitude	Positive or negative feeling about MMS
Subjective Norms	Degree of perception of how important others believe they should use MMS
Facilitating Conditions	Degree to which a person believes that the required support use of MMS exists
Self Efficacy	Degree to which a person's self confidence in their ability to use the MMS
Perceived Ease of use	Degree to which a person believes that MMS would be free of effort
Trust	Trust includes ability, benevolence and integrity of the MMS
Intention	A person's readiness to adopt MMS

## 4 RESULTS

### 4.1 DATA COLLECTION

Samples were taken randomly from the populations with experience and from those with little or no experience in MMS usage. Data was collected from different parts of Nairobi and Chennai. The samples were categorized into slum dwellers (A), rural dwellers (B), and suburb dwellers (C). The questionnaires were distributed as follows. A=100, B=100 and C=122 in the two countries. The total number of distributed questionnaires was 322 out of which 82 were incomplete in Chennai and 50 were incomplete in Nairobi. The sample sizes for this study was 240 in India and 272 in Kenya.

### 4.2 DATA ANALYSIS

This research employed partial Least Squares (PLS) to perform data analysis.

#### For India

*Table 2: Chennai Data Summary*

Variable	Classification of variable	Frequency	Percentage
Gender	Male	200	83.3%
	Female	40	16.7%
Age	Less than 20 years	2	0.83%
	Between 20-30 years	158	65.8%
	Between 30-40 years	76	31.7%
	Between 40-50 years	3	1.25%
Marital status	More than 50years	1	0.41%
	Married	95	39.6%
Education	Single	145	60.4%
	Diploma	17	7.1%
	Intermediate College	26	10.8%
	Bachelor	114	47.5%
Income	Master/PhD	83	34.6%
	Less than ₹2000/pa	12	5.0%
	Between ₹2000-₹4000	58	24.2%
	Between ₹4000-₹6000	67	27.9%
	Between ₹6000-₹8000	52	21.7%
	Between ₹8000-₹10000	10	4.2%
	More than ₹10000	41	17.1%

From table 2 the result shows than a majority of the respondents are male (83.3%) and between 20-30 years old (65.8%). 60.4% are single, 47.5% have a bachelors. A sample population of 27.7% has income between £4000-£6000. Seventeen percent of those with high level of education and are above 30 years old earn more than £10000 per month.

#### For Kenya

*Table 3: Nairobi Data Summary*

Variable	Classification of variable	Frequency	Percentage
Gender	Male	210	77.2%
	Female	62	22.7%
Age	Less than 20 years	5	1.83%
	Between 20-30 years	182	66.9%
	Between 30-40 years	72	26.5%
	Between 40-50 years	10	3.67%
	More than 50years	3	1.1%
Marital status	Married	120	44.1%
	Single	152	55.8%
Education	Diploma	40	7.1%
	Intermediate College	36	14.7%
	Bachelor	143	52.5%
	Master/PhD	53	22.1%
Income	Less than £2000/pa	30	11.02%
	Between£2000-£4000	54	19.8%
	Between £4000-£6000	122	44.9%
	Between £6000-£8000	35	12.9%
	Between £8000-£10000	27	9.92%
	More than £10000	34	12.5%

From table 3 the result shows than a majority of the respondents are male (72.2%) and between 20-30 years old (66.9%). 55.8% are single, 52.5% have a bachelors. A sample population of 44.9% has income between £4000-£6000. Twelve percent of those with high level of education and are above 30 years old earn more than £10000 per month.

#### 4.3 RESULT AND HYPOTHESIS TEST

Table 4 and Table 5 below show the result of testing the research model using PLS analysis. Estimated path coefficients are listed with their respective t-values. Most coefficients in the two countries are significant at 97% significance level, providing strong support for the hypotheses. The result shows the appropriateness of the TPB, TAM and TDTP models in explaining individual behaviour (ICSMPS & Kruse, 2013). The results also support the links for the models representing effects of trust on intention and adoption mobile money services

## For India

Table 4: Result and Hypothesis Test for India

Hypothesis	Effects	Path Coefficient	T-statistics	Remarks
Hyp1	Att on Int	0.390	4.9880	Supported
Hyp2	PBC on Int	-0.017	-0.6271	Not supported
Hyp3	SC on Int	0.120	2.0541	Supported
Hyp4	Tr on Att	0.156	3.3764	Supported
Hyp5	Tr on PBC	0.372	7.6993	Supported
Hyp6	Tr on SC	0.189	2.7045	Supported
Hyp7	Tr on Int	0.131	2.1760	Supported
Hyp8	Tr on PU	0.203	4.0311	Supported
Hyp9	PEU on PU	0.568	12.9295	Supported
Hyp10	PEU on Tr	0.385	7.4461	Supported
Hyp11	PEU on Att	0.154	2.1761	Supported
Hyp12	PU on Att	0.543	7.1568	Supported
Hyp13	PU on Int	0.313	3.7022	Supported

## For Kenya

Table 5: Result and Hypothesis for Kenya

Hypothesis	Effects	Path Coefficient	T-statistics	Remarks
Hyp1	Att on Int	0.387	4.9850	Supported
Hyp2	PBC on Int	-0.019	-0.6273	Not supported
Hyp3	SC on Int	0.118	2.0537	Supported
Hyp4	Tr on Att	0.152	3.3760	Supported
Hyp5	Tr on PBC	0.371	7.6990	Supported
Hyp6	Tr on SC	0.182	2.7055	Supported
Hyp7	Tr on Int	0.132	2.1759	Supported
Hyp8	Tr on PU	0.213	4.0321	Supported
Hyp9	PEU on PU	0.635	12.9364	Supported
Hyp10	PEU on Tr	0.392	7.4470	Supported
Hyp11	PEU on Att	0.150	2.1756	Supported
Hyp12	PU on Att	0.537	7.1559	Supported
Hyp13	PU on Int	0.325	3.7032	Supported

## 4.4 RESULT ANALYSIS

From the table 4, the results for India show that the;

- (i) Intention to use MMS is predicted by attitude ( $\beta = 0.390$ ,  $p < 0.01$ ), subjective Norms ( $\beta = 0.120$ ,  $p < 0.05$ ), trust ( $\beta = 0.131$ ,  $p < 0.05$ ), and perceived usefulness ( $\beta = 0.313$ ,  $p < 0.01$ ).
- (ii) Attitude to use MMS is predicted by trust ( $\beta = 0.156$ ,  $p < 0.01$ ), perceived usefulness ( $\beta = 0.543$ ,  $p < 0.01$ ), and perceived ease of use ( $\beta = 0.154$ ,  $p < 0.05$ )
- (iii) Perceived usefulness is predicted by perceived ease of use ( $\beta = 0.568$ ,  $p < 0.01$ ), and trust ( $\beta = 0.203$ ,  $p < 0.01$ ).
- (iv) Trust is predicted by perceived ease of use ( $\beta = 0.385$ ,  $p < 0.01$ ),
- (v) Trust has a positive effect on attitude ( $\beta = 0.156$ ,  $p < 0.01$ ), subjective norm ( $\beta = 0.189$ ,  $p < 0.01$ ), and perceived behavioral control ( $\beta = 0.372$ ,  $p < 0.01$ ).

## (a) Intention towards MMS

- (i) The intention to use MMS is jointly predicted by attitude ( $\beta = 0.390$ ), subjective Norms ( $\beta = 0.120$ ), trust ( $\beta = 0.131$ ), and perceived usefulness ( $\beta = 0.313$ ). These variables explain 55.5% of the variance on intention to use ( $R^2 = 0.555$  coefficient of determination). This shows how good and strong the explanatory power of models of intention. If one

compares the results with the previous TPB based studies in IT acceptance, the explanatory power of the current research model for behavioral intention to the use is the higher than the given values of  $R^2=0.42$ .

(ii) Attitude ( $\beta = 0.390$ ) has a significant effect on intention and thereby supporting hypothesis 1. Attitude with the coefficient of 0.39 has the strongest effect. This shows the important role of an individual's attitude in driving their intentions towards adoption of MMS. This concurs with Pratkanis who proposed that attitude strongly affects intention [28].

(iii) The path between trust and intention is significant ( $\beta = 0.130$ ), hence supports hypothesis 7. This finding still supports Pratkanis who proposed a significant relationship between trust and behavioral intention [28].

(iv) The path between usefulness and intention was found to be significant ( $\beta = 0.313$ ) hence supporting hypothesis 13. This is consistent with the findings of [29], [28] who proposed significant correlation between intention and perceived usefulness.

(v) The path between subjective norms and intention was found to be significant ( $\beta = 0.120$ ) hence supporting hypothesis 3. The formative measures considered interpersonal and external influence, family, friends and media. Media and family influences were significant, but the friends influence was minimal. This agrees with the findings by Fiske [29].

(vi) The path between perceived behavioral control was found not to be significant ( $\beta = -0.017$ ) hence rejecting hypothesis 2. These findings are inconsistent with those of Fiske who reported significant relation between behavioral control and intention [29].

#### (b) Attitude towards MMS

(i) The attitude to use MMS is jointly predicted by trust ( $\beta = 0.156$ ), perceived usefulness ( $\beta = 0.543$ ), and perceived ease of use ( $\beta = 0.154$ ) explaining the fifty-five percent variance. The path between perceived usefulness and attitude was found to be significant ( $\beta = 0.543$ ), hence supporting hypothesis This is consistent with other studies by [28] which reported a significant relation between usefulness and attitude. Perceived usefulness has the strongest path coefficient of 0.543 emphasizing the important role of an individual perception of the usefulness in shaping their attitudes.

(ii) The path between perceived ease of use and attitude was found to be significant ( $\beta = 0.154$ ) hence supporting hypothesis 11. This is consistent with studies by [29] who reports a significant relation between perceived ease of use and attitude.

(iv) The path between trust and attitude was found to be a significant ( $\beta = 0.156$ ) hence supporting hypothesis 4. The result supports findings of [29], who found a significant relation between trust and attitude.

#### (c) Perceived Usefulness

(i) Perceived usefulness is predicted by perceived ease of use ( $\beta = 0.568$ ), and trust ( $\beta = 0.203$ ) giving a total variance of 44.5%. The path between perceived ease of use and perceived usefulness was found to be significant, hence supporting hypothesis 9. This is consistent with finding by Myers & Kwon (2013) which also supports the trust relation in the TAM model.

(ii) The path between trust of use and perceived usefulness was found to be significant ( $\beta = 0.203$ ) hence supporting hypothesis 8. This supports the findings by Venkataraman [14].

When table 5 for result and hypothesis test for surveys done in Kenya is analyzed, the result shows similar characteristics with that of the research sample in India. There is a slight deviation in actual results but the overall summary shows a similar behavioral inclination of Kenyan and Indian mobile money users towards acceptance and usage of the technology.

## 5 DISCUSSION

This research acted to confirm that irrespective of the geographical location, customers' behaviour is one of the most influencing factors for the uptake of a new product. Any Mobile network operator gearing to expand or launch MMs need to consider the following in relation to behavior.

### 5.1 ADOPTION AND USAGE OF MOBILE MONEY

Mobile Money is a service that has two types of clients: customers and users [1]. Failure to distinguish between adoption and usage states leads to misrepresentation of facts. For example, a Mobile Network Operator looks at 2 million accounts opened in 4 four months but fails to analyze how many of these accounts are performing. Since performance is directly related to the revenue, a player with high percentage of non-performing account holders may not survive [1]. Indian Mobile money Operators should have a clear strategy not to just rush for customers and end up with nonperforming clients.

## **5.2 KNOWLEDGE OF PRODUCT LIFE CYCLE**

This is the “birth and death” of a product or a service [2]. The cycle includes four main phases – introduction, growth, maturity, and decline [2]. At introduction the product is unfamiliar to the majority of customers hence they become cautious about it [11] but at growth level, customers become more familiar with the product resulting in increased adoption. At maturity a high number of customers, stiff competition, and many incentives distinguishing one player from another come into play [11]. The last level is the decline where saturation of the product and customers increasingly become disinterested and start looking for a more superior product [11]. The Indian MNO must understand the level at which Mobile Money Sector is at to make an informed decision.

## **5.3 TECHNOLOGY DIFFUSION CURVE**

Product Diffusion theory helps one to understand the customers’ uptake behavior of a given product or service over a period [6]. Adoption of the new product falls into five categories including Innovators (2.5% of the market), Early Adopters (13.5%), Early Majority (34%), Late Majority (34%) and the Laggards marking sixteen percentage of the market.

Mobile money operators must exercise caution on using the behaviour of innovators and early adopters to project future performance [12]. For example, WIZZIT in South Africa had an exponential mobile money customer growth within the first three years. However, the trend suddenly changed to a modest growth, which fell below its projections [3]. This is because of the innovators. With the knowledge that different sections of adopters respond differently to a new product or service, Indian mobile money operators have an upper hand in planning for expansion or a new launch.

## **6 CONCLUSIONS**

In conclusion, three important recommendations for the mobile operators gearing for the liberalization of the Mobile Money sector in India include:

### **6.1 CAPITALIZE ON THE FIRST TWO SEGMENTS**

In a country like India where mobile money services are relatively scarce, firms have to concentrate on the early adopters and innovators [6]. Since the innovators and early adopters go in for innovative products, the mobile money services must invest heavily in ensuring the products offered meet customers’ taste. Mobile companies also need to guard their market by responding quickly to the needs of their customers lest a competitor with superior products snatch them away.

### **6.2 USE TRIALS TO DEVELOP CUSTOMER CONFIDENCE AND EARN TRUST**

Since MMS deals with money, new customers are concerned with reliability, and safety of the service and the providers. To build the confidence and trust in the mobile money services, provider companies must offer trials to potential customers [13]. These may include free registration, zero transaction charges, and free airtime top up for customers during the pilot period [13]. For example, in 2006 the Mpesa pre-launch strategy in Kenya included free registration of five hundred customers in the three neighboring districts to Nairobi [6]. Pilot customers had a privilege of carrying out transactions free of charge for a couple of months. This strategy worked as many people sought to register as Mpesa users [19].

### **6.3 UNDERSTAND THE TECHNOLOGY CURVE OF MOBILE MONEY SERVICE**

It is important for the mobile operators in India to appreciate the stage where this innovation is at on the technology adoption curve [6]. Companies must analyze customer types to determine the category and the fraction actively using the services [6].

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