ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

DRYING CHARACTERISTICS OF LOW FAT CHICKEN CUBES AND EFFECT OF SODIUM CHLORIDE REPLACEMENT ON PHYSICAL, TEXTURAL, AND REHYDRATION PROPERTIES

AISHA TABASSUM, V. K. SHIBY* and M. C. PANDEY

Freeze Drying and Animal Products Technology Division, Defence Food Research Laboratory, Siddarthanagar, Mysore, Karnataka 570 011, India

Manuscript Info

Manuscript History:

Received: 15 August 2015
Final Accepted: 22 September 2015
Published Online: October 2015

Key words:

Chicken cubes, Whey protein concentrate, Rehydration, Texture , Drying Kinetics

****Corresponding Author***

AISHA TABASSUM

Abstract

Low fat chicken cubes containing whey protein concentrate and varying salt combinations (NaCl and STPP) were developed and evaluated for rehydration characteristics, shrinkage and texture. The hardness of the samples varied between 0.9 and 2.4 N. Sample containing 2.5% NaCl and 1% STPP exhibited good textural properties. Lewis & Modified Page models gave satisfactory prediction of hot air drying data ($R^2 > 0.98$) for varying thickness at 70 °C. The prediction accuracy was higher for Lewis model at low sample thickness. The sample with 0.5 cm thickness, containing 2.5 % NaCl and 1% STPP was found to have minimum drying time (6h) and good rehydration characteristics The bulk density, pH and a_w values were 0.413g/cm^3, 5.53 and 0.273 respectively. Low fat chicken cubes had a shelf life of 12 months at ambient conditions.

INTRODUCTION

Meat products are popular in the world for economic reasons and they provide mixture of proteins and other nutrients to the consumers, which are desirable from nutrition point of view. As of now, not many shelf-stable extended meat products are available in the market, so development and quality evaluation of an easily rehydratable, tasty, convenient and nutritious meat product will be of much significance. Many ground, formed and whole muscle products rely on various non meat additives as binders, fillers or extenders to improve product characteristics and to reduce production costs. These ingredients usually consist of non meat proteins (e.g., dairy, soy) or polysaccharides (e.g., starch, carrageenan) that are used as binders, fillers or extenders to improve the meat product characteristics and control production cost (Corner, 1979; Smith and Rose, 1995; Barbut, 2002). The selection of suitable binder has implications on the binding characteristics and hardness of the product. Modi and Prakash (2008) reported that pearl millets, carrots, cabbage, potato and skimmed milk powder were compatible in the formulation of meat cubes. Barbut (2006), studied the interactions between meat and non meat binders with respect to their contribution to meat gel microstructure. Milk proteins have been reported in many studies to exhibit functional properties as water and fat binders have the potential to modify the textural characteristics of low fat meat products (Lucca and Tepper, 1994). Whey protein acts as fat mimetic which reduces food calorie but at high temperature it may undergo caramelization and denaturation (Anjaneyulu et al., 2013).

Phosphates are also used to enhance the characteristics like cooking performance. In addition, they can improve the nutritional value of foods, an important benefit to increasing numbers of health-conscious consumers. STPP is a colorless inorganic salt. It binds strongly to metal cations as both a bidentate and tridentate chelating agent. It can be used to preserve foods such as red meats, poultry, and seafood, helping them to retain their tenderness and moisture.

Water activity, probably is the most important single factor for determining the shelf-stability of most dried meats. The main attribute of drying technology is the decrease in the water activity in the product by decreasing its water content, inhibiting the development of microorganisms and decreasing spoilage reactions, thus prolonging the shelf life of the product. An important advantage of dehydrated products is that their costs of packing, storage and transportation are reduced due to the comparatively smaller volume and mass of the dried product (Okos et al., 1992). Furthermore, products with low moisture content can be stored for long periods of time at room temperature (Jarayaman and Das Gupta, 1995). The final product obtained may differ in physico-chemical, nutritional, sensory and rehydration properties and microstructures depending on the drying method used (Caric and Calab, 1987; Caparino et al., 2000). As a result, by choosing the most suitable drying method and conditions, the final product quality and production costs can be controlled. Freeze drying is generally considered as the best method for production of high quality dried products with porous structure and little or no shrinkage, which can rehydrate readily before use. The retention of the nutrients and the aroma is high and a fresh-like product can be obtained Ratti (2001). But, it suffers from high production costs, high energy consumptions and low through puts (Caparino, 2000; Ratti, 2001; Hsu et al., 2003). Hot-air drying is one of the most widely used methods for the conservation of food on a global scale.

Several phenomena related to heat and matter transfers are involved in the dehydration process. The kinetics of matter transfer (mainly water) during the drying process are dependent on the operational control of temperature, relative humidity and flow rate of drying air, as well as product thickness, load density and shape. Mathematical modelling of the drying process is an efficient tool for prevention of product deterioration, excessive energy consumption, equipment stress and decrease in product yields (Olivas et al., 1999). Several authors have proposed that the predominant mechanism in a food drying process is the diffusive movement of water from within the food to the surface in contact with the drying air. The theory of diffusion, however, does not consider shrinkage and case hardening of the product (Van Arsdel and Copley, 1963). The present study was carried out to study the rehydration characteristics of dehydrated chicken cubes formulated with whey protein and other additives. The textural characteristics and rehydratability of chicken cubes obtained with varying salt combinations were compared to devise an optimum combination of NaCl and STPP. The variation in drying time and moisture ratio as a function of product thickness was also evaluated.

MATERIALS AND METHODS

Preparation of Chicken Cubes

Chicken breast meat (pH 5.9) procured from Mysore local market was used for the present study. The chicken was manually deboned, was trimmed of any visible fat, chopped into small pieces, washed, marinated and cooked with addition of spices. The cooked chicken was mixed with WPC and corn flour and minced by using meat mincer (Sirman, Italy) fitted with 5 mm plate. The blend was minced at 1400 rpm. The minced mix was then formed into dough and shaped into chicken cubes of 0.5, 1 and 1.5cm thickness using a stainless steel mould and dried using various drying methods. The blend optimization was carried out based on the sensory and rehydration properties of the product (data not shown). The sample containing chicken solids, WPC and Corn flour in the ratio 60: 20: 20 were used for further experiments. Different combinations of NaCl and STPP were incorporated in chicken cubes containing WPC and the quality characteristics were evaluated with respect to the texture, rehydration and shrinkage. The chicken cubes contained chicken solids: WPC: Corn flour in the ratio 60: 20: 20. The proximate composition of extended chicken cubes is shown in Table 1.

Hot air drying of Chicken Cubes

The best combination selected was further used for establishing the drying kinetics and modelling of the drying behaviour with varying sample thickness. The chicken cubes of various thicknesses (0.5, 1, 1.5cm) were subjected to hot air drying in a cabinet dryer for 7 h at 70°C with velocity of air circulation 0.5 -1 m/sec. The variation in drying time with varying thickness and also the change in moisture ratio with the progress of drying time were studied to get a better understanding of the hot air drying process. A convective air dryer (Heating Equipments Manufacturing Co. Madras) was used. All interior parts of the tray dryer including trays were made of SS-304 and 5 cm thick insulation was provided on all sides of the dryer. A vent for sensor was provided in the top centre to insert a probe.

A digital temperature indicator attached with chromel-alumel thermocouple measured dry bulb and wet bulb temperatures of inlet and exhaust air. Dry bulb temperature of mixed air was also measured with the temperature indicator. The temperature of heated air was displayed on the control panel, which was measured by PT-100 sensor.

Experimental design

Three sample thicknesses (0.5cm, 1cm and 1.5cm) were used to study the effect of sample thickness on drying behaviour at 70°C and 2.5 m/s air velocity. The chicken cube samples with varying thickness were spread over an area of 375×10^{-4} m^2. In order to prevent sticking and to facilitate easy removal of the sample after drying, the tray was lined with 90 µm thick polyethylene sheet. Once the desired air temperature and velocity was attained in the dryer, three trays with the sample were loaded in the drying chamber. The clearance between the trays was 100 mm. The door of the dryer was properly closed to prevent air leakage. The initial moisture content of the cubes was determined. To record the moisture loss during drying the trays were taken out of the dryer at regular intervals, weighed by using an electronic balance and quickly replaced inside the dryer. It was assumed that brief interruptions (less than 30 s) did not interfere with the drying process. The product temperature during the experiments was recorded at regular intervals. Moisture content of the product at different stage of drying process was calculated and that of the final product was determined by drying in a vacuum oven at 70 ºC and 450 mm Hg pressure.

Modelling of Convective air drying

A wide range of empirical models were used to express the thin layer drying behaviour of food materials. The selected models were Lewis (Bruce, 1985), Modified Page (Diamente and Munro, 1993), Henderson and Pabis (Doymaz, 2004)), Logarithmic (Temple and Van Boxel, 1999). These models are described in Table 2. In these models the relationship between moisture ratio of material is expressed as function of drying time, t(s) as

$$\frac{M - Me}{Mi - Me} = f(\mathrm{t}) \qquad (1)$$

where M is the moisture content of the product at anytime, t (kg water kg dry solids^{-1}) , Me is the equilibrium moisture content of the product (kg water kg drysolids^{-1}) and M_i is its initial moisture content. In these models given in Table 2, MR is the moisture ratio (dimensionless), t(s) is the drying time and k, n, a, b, c are the model constants. Origin 6.1, a statistical software package was used to calculate the constants of the selected models. To evaluate the fitting of the models, in addition to R-square values, reduced –Chi-square values were also compared. A model with highest correlation coefficient (R) and lowest chi-square value was considered as having best fit.

Chi-square was calculated by the following formula

$$\chi 2 = \sum_{1}^{N} \frac{(M\,\mathrm{Re}\,xp,i - MRpre,i)^2}{N - n} \qquad (2)$$

where $MR_{exp,i}$ and $MR_{pre,i}$ are the experimental and predicted moisture ratios respectively. N is the total number of experiments and n is the number of model constants.

Bulk density and colour change

Bulk density was determined by making the cubes fall freely into a measuring cup of 100 ml volume from a height of 10 cm and by weighing the contents of the cup. The colour were measured as L, a, b values using Hunter colorimeter (Hunter Lab, Reston, VA, United States of America) as given by Shand (2000). The colour change ΔEc of samples during drying was estimated using the equation 1.

$$\Delta Ec = \sqrt{(Li - Lr)^2 + (ai - ar)^2 + (bi - br)^2} \quad ....(1)$$

where Li, ai, bi are colour values of chicken cubes before drying and Lr, br, ar are colour values of rehydrated samples respectively.

Water activity and pH

Water activity was determined using water activity meter (Aqua Lab Decagon Devices Inc., Pullman, Washington, United States of America). pH of the chicken cubes were determined using microprocessor controlled digital pH meter (Systronics, India).

Texture

Texture profile analysis of chicken cubes was conducted using Texture Analyser (TA Plus, Lloyd Instruments, Hampshire, United Kingdom) as per the method described by Bourne (1976). Rehydrated samples were compressed twice to get an imitation of mastication which included first and second bite. They were placed on the fixed platform and compressed to 85% of their original height. A 5mm cylindrical probe was used, connected to the moving crosshead which was cycled at a pre and post test speed of 30 mm/ min. The maximum clearance between the moving cross head and sample was maintained at 3mm throughout the study. The measured and derived parameters like hardness (N) springiness (mm), cohesiveness, gumminess (N) and chewiness (Nmm) were estimated using Nexigen software. Results were obtained as an average of triplicate values.

% Shrinkage

The shrinkage of the dried chicken cube was measured by a volumetric replacement method using toluene as a working liquid. Percentage of shrinkage was calculated as follows:

$$\% \text{ Shrinkage} = \frac{V_0 - V}{V_0} \times 100$$

where V_0 is the initial volume of chicken, m^3; and V is the volume of dried chicken, m^3.

Rehydration characteristics, rehydration ratio and % rehydration

Rehydration properties of the chicken cubes were evaluated using standard analytical procedures (AOAC, 1990; Ranganna, 1986). Sample rehydration was performed in boiling water (1:20). The duration of rehydration was noted for each sample, as the time period after which there was no more absorption of water by the samples. Percentage rehydration was calculated using following expression

$$Rehydration\,(\%) = \frac{W_r - W_1}{W_0 - W_1} \text{ ---------- (2)}$$

W_r = Weight of rehydrated sample (g)
W_1 = Weight of dried sample (g)
W_0 = Weight of fresh sample (g)

The rehydration ratio was calculated at fixed intervals of time by immersing chicken cubes into boiling water bath, rinsing excess water with kitchen towel and then weighing. The rehydration ratio was calculated using weight of sample before and after rehydration as follows

$$Rehydration\ ratio = \frac{W_1}{W_2} \text{.............. (3)}$$

Where W_1 and W_2 are initial and final weight of dried chicken cubes respectively.

Storage

The chicken cubes were packed in PFP and stored at 25±2°C and 37±2^{0}C. The changes in TBARS, FFA and Browning Index values were evaluated for a period of one year. The moisture and protein content of chicken cubes was determined using the standard (AOAC, 1984) procedures. Fat content of dehydrated chicken cubes was determined as per AOAC (1990). Quality parameter like TBARS was determined as per Taraldgis method 1960, and FFA by titrimetric method (AOAC, 1984).

Statistical Analysis

All experiments were repeated three times and data sets were subjected to analysis of variance (ANOVA) using the general linear models. Significant differences between the samples means were determined at the $p < 0.05$ levels by ANOVA. The data consisting of equilibrium water contents at different temperatures and humidity levels were statistically analyzed and the coefficients of various sorption equations were determined by means of standard regression technique using Origin Pro 8 software.

RESULTS AND DISCUSSION

Quality characteristics of chicken cubes at different salt levels

Whey protein has beneficial effects on protein quality as well as functional characteristics and also serves as a fat replacer to obtain healthier meat products. Chicken cubes were formulated with WPC, Corn flour and cooked chicken mince. The whey protein exhibited a positive effect on the colour retention of chicken cubes during drying. Quality evaluation of the optimized sample was carried out and subjected to storage studies at two different temperatures.

Different parameters like shrinkage, rehydration time, % rehydration, rehydration ratio, % yield and moisture content in the samples was evaluated (Table 3) and correlated with sensory data. Chicken cubes prepared using different levels of NaCl and STPP had significant effect on shrinkage. The combination of 2.5% NaCl and 1.0% STPP showed less shrinkage (11%) while the samples prepared using NaCl alone and in combination with 0.5 % STPP showed more shrinkage (25%). STPP have been implicated in reducing shrinkage of lean meat (Werbicki et al., 1976) and ground meat (Kembi and Okubanjo, 1989). Phosphates in the presence of sodium chloride are known to enhance dissociation of actomyosin, thus making it more soluble (Truot and Schmidt, 1984). Furthermore the effect of polyphosphate on myofibrilar proteins in the presence of sodium chloride is an irreversible dissociation of actomyosin, a phenomenon that has been shown to be heat stable (Shultz et al., 1972). The rehydration time was minimum for the chicken cubes prepared with 2.5% NaCl and 1% STPP (45 min) and maximum for the samples prepared using NaCl alone (60 min) while for the samples prepared using 3% NaCl+0.5% STPP and 2.0 % NaCl+ 1.5% STPP the rehydration time was similar. Rehydration ratio indicates the capacity to absorb water and to hold soluble solids in dried matrix. It is clear from Table 3 that the rehydration ratio and % rehydration is more for the samples prepared using 2.5% NaCl and 1% STPP and minimum for the samples prepared using NaCl alone. STPP either individually or when combined enhance moisture retention in spite of long period of heat treatment and consequently increase product yield and moisture content. The product yield in the samples prepared using 2.5% NaCl and 1% STPP was around 39% while in the samples which are prepared using NaCl alone and with 0.5% STPP it was comparatively low. The samples prepared with 2% NaCl and 1.5% STPP showed higher yield. The moisture content was found to be higher in the sample containing 1.5% STPP indicating improved WHC of WPC in the presence of salts.

Texture profile of chicken cubes

Texture is an important parameter which defines the commercial value of meat and meat products. Texture and tenderness are rated as the most important of all the attributes of eating quality (Lawrie, 1998). Texture of meat is strongly dependent on the meat protein level (Pietrasik and Shand, 2003). Meat protein ratio (MPR) expresses percentage moisture divided by percent protein and is commonly used to classify dried sausages and other meat products. .Chicken cubes containing different salt combinations had MPR of ≤ 1.9:1 as specified for shelf stable dry sausages. Salt concentration has an influence on the texture of the product (Arnau, 1991). Physical methods of measuring texture include the following; measuring the shear force (Warner, 1928), penetration force (Tressler et al., 1932) force required to cut (Miyada and Tappel, 1956), force required to puncture compression force and tensile force. Ruiz de Huidobro (2005), reported that texture profile analysis (TPA) method is the best predictor of sensory texture for bovine meat. The Warner-Bratzler shear test measures the force necessary to shear a piece of meat, whereas TPA measures the compression force.

A good understanding of physicochemical, structural and functional properties of milk proteins under addition of salts is not only momentous for fundamental research but also for the improvement of meat products in which functional dairy proteins are incorporated in combination with salts. Whey proteins are among the most employed and versatile source of functional and nutritional food proteins.

In our study, chicken cubes were prepared using different proportions of NaCl and STPP in combination with WPC. And the results of TPA of these samples are shown in Table 4. The total salt concentration in the blend was maintained as 3.5%. NaCl was partially replaced by STPP up to 1.5%. Two samples (S2 and S3) containing STPP up to 1% showed lower hardness than control sample containing NaCl alone (S1) whereas the 4th sample (S4) containing 1.5% STPP was found to be harder than the control. STPP up to 1% has positive effect on reducing/lowering hardness. The hardness was minimum (1.07 N) in the sample prepared with 2.5% NaCl and 1% STPP and maximum (2.46 N) in the sample prepared with 2% NaCl and 1.5% STPP. All the above parameters were correlated to sensory data. The chicken cubes prepared using 2.5% NaCl and 1% STPP had highest acceptability rating of 8.5 on a 9 point hedonic scale.

The cohesiveness increased as STPP content was increased to 0.5% and 1.5% and reduced when excess STPP was added (1.5%). Sample (S1) showed less cohesiveness and sample (S3) showed maximum cohesiveness while sample (S4) showed comparatively low cohesiveness compared to control sample (S1). The springiness increased from sample (S1) to (S3) and decreased in sample 4. Control sample (S1) showed less springiness and sample (S3) showed more springiness. The gumminess and chewiness was less in sample (S3) indicating good textural attributes. The same trend was observed in the low fat chicken nuggets containing reduced NaCl with incorporation of apple pulp (Arun et al., 2010). Fracture force and adhesive force decreased in sample containing 2.5% NaCl + 1% STPP indicating softer texture or meat tenderness. This trend could be well correlated with the hardness data. Similar results have been reported by Purslow (1985), in pork loin. The adhesiveness and stiffness was also low in sample containing 2.5% NaCl + 1% STPP. Better hardness and cohesiveness values observed in chicken cubes might be due to the formation of good quality gel matrix as a result of reduced muscle protein denaturation. Similar results have been observed in in pork nuggets with lower levels of fermented bamboo shoot mince (Thomas, Anjaneyulu and Kondaiah 2008a). Feng and Xiong (2002) observed that the quality of gel matrix had an important role in determining textural properties of cooked frankfurters. Also, a reduction in chewiness, gumminess and hardness in fermented sausages (Gou et al., 1996) and decrease in springiness in salami type products (Barbut, 2005), with decrease in emulsion pH was reported.

Texture is affected by drying jerky at high temperatures for extended periods of time (Calicioglu et al., 2002). It was reported by El-Shimi (1992), that the penetration force required is higher for microwave cooked roast beef than for conventionally cooked roast beef. Texture Technologies Corporation (2005), has tested the textural properties of restructured jerky against the traditionally made jerky. Very limited works have been reported on the textural characteristics of dried meat products. As the product quality mainly relies on its textural properties for market value, it is vital to investigate the effect of different parameters involved in its processing such as pH, water activity, salt content and method of drying.

As our results indicate the possible gelation properties of whey proteins in the presence of salts to obtain a stable gel which doesn’t disintegrate during rehydration process, the study throws light on performance of NaCl and STPP in the presence of WPC in an actual complex food system. Whey proteins in restructured chicken cubes exhibited good water holding capacity under the influence of monovalent and polyvalent salts .This agrees with the findings of earlier workers who have reported the mechanism of whey protein soluble aggregates thermally treated with Nacl having better stability than native proteins. Addition of NaCl also enhanced the formation of denser aggregates (Choi et al., 2000; Kuhn et al., 2011; Ryan et al., 2012).

Effect of sample thickness on hardness, shrinkage and rehydration properties of chicken cubes

The chicken cubes prepared having different thicknesses had a significant effect on shrinkage probably due to interactions with other components in the matrix resulting in solubilisation of protein. Percentage shrinkage was minimum (9%) for samples which had lower thickness, 0.5cm and maximum (13%) for the samples which had higher thickness 1.5cm. Rehydration time and rehydration ratio increased with increase in sample thickness. % rehydration decreased as thickness of the chicken cubes increased (Table 5). Samples with low thickness showed minimum hardness and with higher thickness showed more hardness. Overall chicken cubes prepared with 2.5% of NaCl and 1% STPP and having a thickness of 1 cm showed best quality attributes.

Effect of sample thickness on drying characteristics of chicken cubes (drying time, drying rate)

The initial moisture content was 0.8 kg water kg dry solids^{-1} and the final moisture content was 0.02 kg water kg dry solids^{-1}. The change in the values of moisture ratio with time of drying for different sample thickness and different air temperatures at a constant air velocity of 2.5ms^{-1} are plotted in fig 1 to 4. It is observed from these plots that the slope of the curves changed continuously from the initial time of drying. The drying of cubes took place in the falling rate period as noted by the absence of constant drying rate from the graphs. The absence of constant drying rate in the present case is in agreement with results reported by many researchers (Jena and Das, 2007; Akgun and Doymaz, 2005; Gogus and Maskan, 2001; Shiby and Mishra, 2008). Drying time increases with increase in sample thickness. Similar results were also reported for food products and casein curd by other researchers (Maskan and Gogus, 1998; Sogi et al., 2003; Phoungchandang and Woods, 2000; Espie et al., 1984). The drying time to achieve a final moisture content of 0.02kg water kg dry solids^{-1} was 6h at sample thickness of 5 mm which increased to 9h for sample thickness of 15mm at 70 °C temperature and 2.5m/s air velocity.

Modelling of drying characteristics

The drying data obtained from the experiments were fitted to 4 selected models mentioned in Table 2. The values of constants and goodness of fit characterized by (R^2) and reduced (χ^2) values have been shown in Table 6 for groups of experiments conducted using air velocity 2.5 m/s, at 70^0 C and varying sample thickness.

From Table 2 it has been deduced that for chicken cubes with lower thickness (0.5 cm), the prediction accuracy of the models were in the order Modified page > Lewis>Henderson & Pabis > Logarithmic. For samples above 1 cm thickness the prediction accuracy was in the order Lewis > Henderson and Pabis > Modified Page > Logarithmic. For all the thickness studied Logarithmic model gave a poor fit than other models considered. The Chi-square values for Lewis model varied between 0.00074 and 0.00133 for the drying experiments conducted with varying sample thickness. The reduced Chi-square values of Modified page model did not exceed 0.00159 under any of the drying conditions studied. The drying characteristics were satisfactorily described by Modified Page, Lewis and Henderson & Pabis models. Prediction accuracy of selected drying models for chicken cubes of varying thickness at drying temperature 70° C and air velocity 2.5 ms^{-1} are shown in Fig 1 to 4. From these figures, the deviation of predicted values from experimental values for can be seen for varying sample thickness and using different models.

Proximate composition, quality characteristics and storage study of optimized sample

The extended chicken cubes contained lower fat and higher protein than control sample. The moisture content was low in the treated sample and there was not much difference in the carbohydrate level in both control and treated sample. The total energy value in sample containing WPC was 398 kcal/100g. The bulk density of this sample was 0.413g/cm3. The L value was 60.29, a* value 12.2 and b* value was 33.96. The color change (ΔE) during drying was found to be 15.6. The water activity and moisture content were 0.273 and 3.28 in the sample and pH was 5.53. Meat protein ratio (MPR) expresses percentage moisture divided by percent protein and is commonly used to classify dried sausages and other meat products. These values indicate the degree of product drying and shelf stable dry sausage must have an MPR of ≤ 1.9:1. The MPR of chicken cubes containing different salt combinations were found to be well within this limit to confirm the stability of these dehydrated products.

In the case of hot air dehydration of meat, lipid oxidation has been reported to be the major problem limiting the acceptability (Radhakrishna et al., 1988). The dehydrated chicken cubes with WPC are low fat products containing less than 10% fat and hence their shelf life is not limited by lipid oxidation as in the case of other meat products. The chicken cubes were subjected to storage study at different temperatures RT and 37^0C. The FFA and TBARS values were evaluated periodically. Initial FFA value in the sample was 0.3% (expressed as % Oleic acid) and increased to 0.9 % at RT and 1.53 % at 37 ^{0}C respectively. The initial TBARS value was 0.008 mg malonaldehyde/ Kg sample and increased to 0.023 mg and 0.031 mg at RT and 37^0C respectively, indicating no oxidative rancidity development in the sample even at the end of one year. The initial browning index value was 0.051 and final value at the end of storage period was 0.086 indicating there was not much browning or color change in the sample. An increase in FFA levels in meat products during storage has also been observed in other studies (Modi et al., 2004a; Modi et al., 2004b; Modi et al., 2007; Rao et al., 1996). FFA formation is by hydrolysis reactions within lipids (Perkins, 2006) and their accumulation can be used as an indicator of lipid breakdown. Rao et al., (1996) investigated the effects of cooking and storage on buffalo meat in terms of lipid deterioration and cholesterol oxides. It was found that FFA levels increased during both refrigerated and frozen storage of both raw and cooked meat. COPs increased in the meat after cooking and during storage, and TBARS values increased during storage, indicating an increase in rancidity. TBARS values were directly related to changes in storage temperature, underlining the importance of temperature effects on food quality during storage. The same group also looked at the quality of buffalo burger meat with different legume flour binders and during frozen storage (-16 ± 2°C) for four months. FFAs and TBARS both increased during storage, but the products were still acceptable after the storage period (Modi et al., 2004a). Chicken nuggets stored frozen (-18 ± 2°C) for six months were also found acceptable, despite increases in FFAs and TBARS values (Modi et al., 2004b).

TABLE 1. PROXIMATE COMPOSITION OF CONTROL AND EXTENDED CHICKEN CUBES

Parameter (%)	Control	Sample
Protein	20±0.1	31.75± 0.2
Fat	11± 0.2	5.38± 0.1
Carbohydrates	58.5±0.3	54.74± 0.3
Moisture	4±0.3	3.11± 0.2
Ash	6.5±0.2	4.56± 0.05
Energy Value	413 kcal/100g	398 kcal/ 100g

Values are shown as means ± standard deviation (n = 8).

TABLE 2. MATHEMATICAL MODELS USED

Model	Expression	Reference
Lewis (Lewis, 1921)	$M_R=\exp(-kt)$	Bruce, 1985
Modified Page	$M_R=\exp[-(kt)^n]$	Diamente and Munro(1993)
Henderson and Pabis(Henderson and Pabis, 1961)	$M_R=a \exp[-kt]$	Doymaz (2004)
Logarithmic	$M_R=a \exp[-kt] +c$	Temple and Van Boxel (1999)

TABLE 3. REHYDRATION CHARACTERISTICS OF CHICKEN CUBES AT DIFFERENT SALT LEVELS

STPP+NaCl level (%)	3.5+0	3.0+0.5	2.5+1.0	2.0+1.5
Shrinkage (%)	25±1.6	25±1.6	11±1.2	33±1.9
Rehydration time (min)	60±2.0	50±1.8	45±1.6	50±1.8
% rehydration	90± 2.1	92±2.2	95±2.5	90±2.1
Hardness (N)	1.27±0.19	1.65±0.22	1.07±0.14	2.46±0.34
Rehydration ratio	1.87±0.26	1.95±0.28	2.26±0.31	2.10±0.29
% yield of dehydrated chicken cubes	35±1.23	37±1.80	39±2.51	45±2.70
Moisture content g/g db	0.052±0.01	0.030±0.007	0.027±0.005	0.041±0.009

Sensory Characteristics				
Flavour	8.2 ±0.2	8.4 ±0.1	8.3 ±0.2	7 ±0.1
Tenderness	7.5±0.2	8.0±0.2	8.2±0.1	7.8±0.2
Juiciness	7.5±0.3	8.2±0.1	8.3±0.2	7.8±0.2
Acceptability	7.8±0.2	8.3±0.3	8.5±0.3	7.5±0.3

Values are shown as means ± standard deviation (n = 8).

TABLE 4. TEXTURE PROFILE OF CHICKEN CUBES

Sample	Different salt combinations	Hardness1 (N)	Cohesiveness	Springiness (mm)	Gumminess (N)	Chewiness (Nmm)	Adhesiveness (Nm)
S1	NaCl (3.5%)	1.27±0.05	0.23± 0.02	5.73± 1.12	0.29±0.05	1.70 ±0/09	0.0005
S2	NaCl (3%)+ STPP (0.5%)	1.25±0.08	0.26 ±0.04	10.74±1.52	0.43± 0.03	4.66 ±1.51	0.0004
S3	NaCl (2.5 %) + STPP (1%)	1.07±0.05	0.27± 0.05	11.90±2.23	0.29±0.05	3.47 ±1.42	0.0002
S4	NaCl (2 %) + STPP (1.5%)	2.46±0.91	0.18±0.01	11.22 ±2.01	0.45± 0.02	5.07± 1.21	0.0007

Values are shown as means ± standard deviation (n = 8).

TABLE 5. EFFECT OF SAMPLE THICKNESS ON HARDNESS, SHRINKAGE AND REHYDRATION PROPERTIES OF CHICKEN CUBES

Sample thickness (cm)	0.5	1.0	1.5
Shrinkage (%)	9±1.3	11±1.6	13±1.8
Rehydration time (min)	30±2.1	45±2.4	60±2.6
% rehydration	97±1.5	95±1.8	90±2.0
Hardness(N)	0.74±0.16	1.07±0.62	1.43±0.71
Rehydration ratio	1.65±0.72	2.26±0.81	2.31±0.92

Values are shown as means ± standard deviation (n = 8).

TABLE 6. VALUES OF MODEL CONSTANTS AND STATISTICAL RESULTS FOR DRYING EXPERIMENTS USING VARYING SAMPLE THICKNESS AT 70◦ C AND AIR VELOCITY 2.5 (ms^{-1})

Model name	Sample thickness (cm)	Model constant	Estimated Parameter	Adj. R-Square	Reduced χ^2
	0.5	k	.00009	0.99421	.0007
Lewis	1	k	.00008	0.9875	0.00157
	1.5	k	.00005	0.9871	0.00133
		a	0.93465		
	0.5	k	.0001	0.97286	0.00339
		c	0.1		
		a	0.9445	0.97083	0.00371
Logarithmic	1	k	.0001		
		c	0.1		
		a	0.90059	0.9698	0.00353
	1.5	k	.00006		
		c	0.1		
	0.5	a	1.01765	0.99365	.0007
		k	.00009		
Henderson & Pabis	1	a	1.02582	0.98684	0.00167
		k	.00009		
	1.5	a	0.97852	0.98792	0.00141
		k	.00005		
		k	.00009	0.99421	.0007
	0.5	n	1.09165		
Modified Page		k	.00008	0.9875	0.00159
	1	n	1.12482		
		k	.00005	0.9871	0.00151
	1.5	n	0.97944		

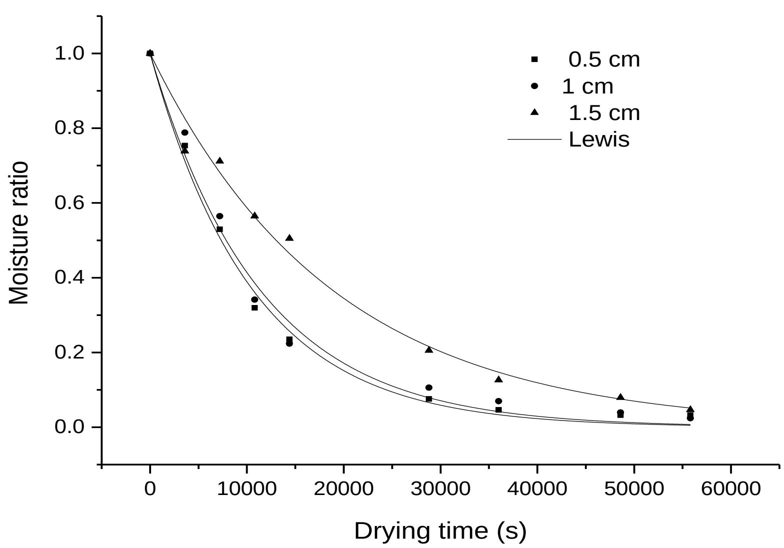

FIG. 1. PREDICTION ACCURACY OF LEWIS MODEL FOR VARIATION OF MOISTURE RATIO WITH DRYING TIME IN CHICKEN CUBES WITH VARYING SAMPLE THICKNESS

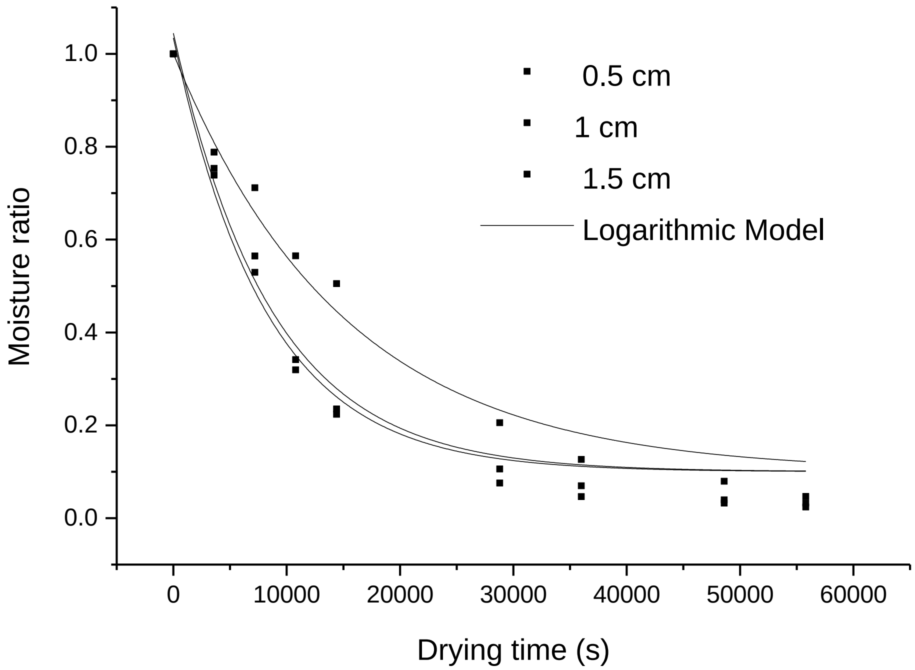

FIG. 2. PREDICTION ACCURACY OF LOGARITHMIC MODEL FOR VARIATION OF MOISTURE RATIO WITH DRYING TIME IN CHICKEN CUBES WITH VARYING SAMPLE THICKNESS

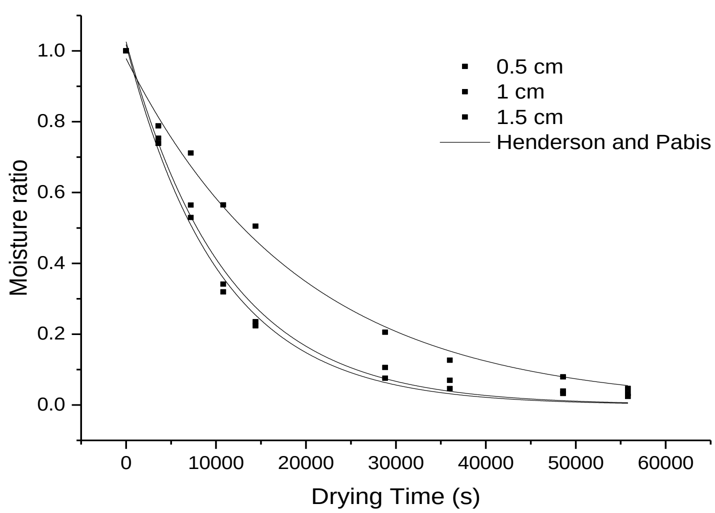

FIG .3. PREDICTION ACCURACY OF HENDERSON PABIS MODEL FOR VARIATION OF MOISTURE RATIO WITH DRYING TIME IN CHICKEN CUBES WITH VARYING SAMPLE THICKNESS

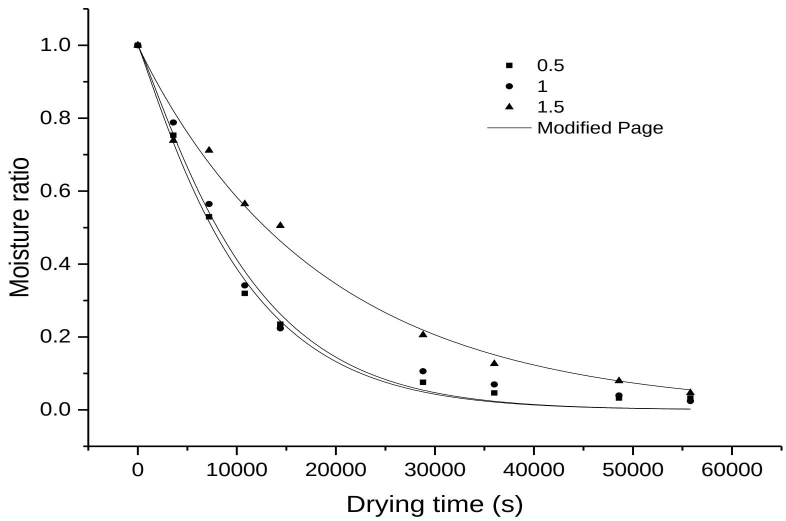

FIG . 4. PREDICTION ACCURACY OF MODIFIED PAGE MODEL FOR VARIATION OF MOISTURE RATIO WITH DRYING TIME IN CHICKEN CUBES WITH VARYING SAMPLE THICKNESS

Conclusion

The hardness of the samples containing varying proportions of NaCl and STPP varied between 0.9 and 2.4 N. Percentage shrinkage was minimum for samples containing 2.5% NaCl and 1% STPP. Sample containing 2% NaCl + 1.5% STPP has lowest hardness, high degree of cohesiveness, optimum chewiness, lowest gumminess, high springiness, low fracture force indicating good textural properties compared to other samples which was well correlated with the sensory data. Drying time of low fat chicken cubes varied from 6h to 9h depending on thickness. The sample with 0.5cm thickness was found to have minimum drying time and good rehydration characteristics. % rehydration increased and rehydration time decreased by reducing sample thickness from 1.5 cm to 0.5cm. For samples with 0.5cm thickness, Lewis Model gave the best prediction of the drying data (R^2 =0.994 , reduced χ^2 =0.00074) and for higher thickness modified page followed by Lewis Model gave good prediction accuracy. The optimum sample was found to have a bulk density of 0.413g/cm^3, pH 5.53, a_w 0.273 and a shelf life of 12 months at both RT and 37^{0}C.

Acknowledgment

Project Funding from DRDO is duly acknowledged.

References

Akgun, N.A. and Doymaz, I. (2005): Modelling of olive cake thin-layer drying process. J. Food Engg., 68: 455–461.

Anjaneyalu, A.S.R., Yhesh, P., Gadekar and Girish Patil, S. (2013): Development in ingredient and processing systems for meat products. In Proceedings of 5th Annual Conference and National Symposium of Indian Meat Association, Hyderabad, India.

AOAC. (1984). Methods of Analysis 14th ed. Association of Official Analytical Chemists, Washington DC.

AOAC. (1990). Official Methods of Analysis. (15th Ed) Association of Official Analytical Chemists, Washington,

Arnau, J. (1991). Thesis of the University at Autonoma de Barcelona-Spain.

Arun, K., Verma, B.D., Sharma, and Rituparna Banerjee. (2010): Effect of sodium chloride replacement and apple pulp inclusion on the physico-chemical, textural and sensory properties of low fat chicken nuggets. Food Sci Technol., 43: 715–719.

Barbut, S. (2002): Protein gelation poultry products processing: An industry guide New York, CRC Press., 277-282.

Barbut, S. (2005): Effect of chemical acidification and microbial fermentation on the rheological properties of meat products. Meat Sci., 71: 397-401.

Barbut, S. (2006): Effects of caseinate, whey and milk powders on the texture and microstructure of emulsified chicken meat batters. LWT, 39: 660–664.

Bourne, M.C. (1976): Texture Profile Analysis. Food Technol., 32 (7): 62-66.

Bruce, D. M. (1985): Exposed layer barley drying, three models fitted to new data up to 150 °C. J. Agril. Engg. Res., 32(4): 337 - 347.

Calicioglu, M. J. N., Sofos, J., Samelis, P. A., Kendall and Smith, G. C. (2002): Destruction of acid and non-adapted *Listeria monocytogenes* during drying and storage of beef Jerky. J. Food Microbiol., 19: 545-559.

Caparino, O.A. (2000): Characteristics and quality of freeze-dried mango powder pre-frozen at different temperatures. J. Philippine Agric. Scientist., 83: 338–343.

Caric, M. and Kalab, M. (1987): Effects of drying techniques on milk powder quality and microstructure: a review. Food Microstructure., 6: 171–180.

Choi, Y.J., Cho, M.S., and Park, J.W. (2000): Effect of hydration time and salt addition on gelation properties of major protein additives. J. Food Sci., 65 (8): 1338–1342.

Corner, F.W. (1979): Functionality of fillers in comminuted meat products. J. Food Sci. Technol., 12: 157-165.

Diamente, L.M. and Munro, P.A. (1993): Mathematical modeling of the thin layer solar drying of sweet potato slices. Solar Energy., 51: 271-276.

Doymaz, I. (2004): Drying kinetics of white mulberry. J. Food Engg., 61(3): 341–346.

El-shimi, N.M. (1992): Influence of microwave and conventional cooking and reheating on sensory and chemical characteristics of roast beef. J. Food Chem., 45: 11-14.

Espie, S. A., Thonpson, C. J., and Winter, G. J. (1984): Drying characteristics of casein curd. NZ Dairy Sci. Technol., 19: 239 - 247.

Feng, J. and Xiong, Y.L. (2002): Interactions and functionality of mixed myofibrillar and enzyme-hydrolyzed soy proteins. J. Food Sci., 67: 2851-2856.

Gogus, F., and Maskan, M. (2001): Drying of olive pomace by a combined microwave-fan assisted convection oven. Nahrung. Food., 45(2): 129–132.

Gou, P., Guerrero, L., Gelabert, J., and Arnau, J. (1996): Potassium chloride, potassium lactate and glycine as sodium chloride substitutes in fermented sausages and in dry cured pork loin. Meat Sci., 42: 37-48.

Hsu, C.L., Chen, W., Weng, Y.M., and Tseng, C.Y. (2003): Chemical composition, physical properties, and antioxidant activities of yam flours as affected by different drying methods. Food Chem., 83: 85–92.

Jarayaman, K. S. and Das Gupta, D. K. (1995): Drying of fruits and vegetables. In A. S. Mujumdar (Ed.), Handbook of Industrial drying. pp. 643–690. New York: Marcel Dekker Inc.

Jena, S. and DAS, H. (2007): Modelling of vacuum drying characteristics of coconut presscake. J. Food Engg., 79: 92-99.

Kembi, S.O. and Okubanjo, A.O. (1989): Effect of polyphosphates and Sodium chloride on pH, Swelling and shrinkage of chevon from west African dwarf goats. J. Food and Agric., In press.

Kuhn, K.R., Fazani Cavallieri, A.L., and Cunha, R.L. (2011): Cold-set whey protein flaxseed gum gels induced by mono or divalent salt addition. Food Hydrocolloids., 25 (5): 1302–1310.

Lawrie, R. A. (1998): Meat Sci. Chapter 10. The eating quality of Meat. VIth edition. 229.Cambridge: Woodhead Publishing Limited.

Lucca, P. A., and Tepper, B. J. (1994): Fat replacers and the functionality of fat in foods. Trends in Food Sci and Technol., 5: 12-19.

Maskan, M. and Gogus, F. (1998): Sorption isotherms and drying characteristics of mulberry (*Morus alba)*. J. Food Engg., 37: 437 - 449.

Miyada, D.S. and Tappel, A.L. (1956): The hydrolysis of beef proteins by various protelytic enzymes. J. Food Sci., 21: 217-225.

Modi, V. K., Mahendrakar, N. S., Sachindra, N. M., and Rao, D. N. (2004b): Quality of nuggets prepared from fresh and smoked spent layer chicken meat. J. Muscle Foods., 15(3): 195-204.

Modi, V., Mahendrakar, N., Rao, N., and Sachindra, N. (2004a): Quality of buffalo meat burger containing legume flours as binders. Meat Sci., 66 (1): 143-149.

Modi, V., Sachindra, N., Nagegowda, P., Mahendrakar, N. and Rao, N. (2007): Quality changes during the storage of dehydrated chicken kebab mix. Intl. J. Food Sci Technol. 42 (7): 827-835.

Modi, V.K., and Prakash, M. (2008): Quick and reliable screening of compatible ingredients for the formulation of extended meat cubes using Plackett–Burman design. LWT - Food Sci and Technol., 41: 878-882.

Okos, M. R., Narasimhan, G., Singh, R. K. and Witnauer, A. C. (1992): Food dehydration. In D. R. Heldman, & D. B. Lund (Eds.), Handbook of food engineering. New York: Marcel Dekker.

Olivas, R., Molina, F. J., Pe´ rez, A. and Ortega, E. (1999): Development of mathematical model for drying of jalapen˜ o peppers in batch process. Conference in meeting of American Institute of Chemical Engineers, New York, USA.

Perkins, E. (2006). Volatile odor and flavor components formed in deep frying. In Erickson, M. (Ed.). Deep Frying, Chemistry, Nutrition and Practical Applications (pp 51-56) Urbana, IL: AOCS Press.

Phoungchandang, S. and Woods, J. L. (2000): Moisture diffusion and desorption isotherms for banana. J. of Food Sci., 65 (4): 651 - 657.

Pietrasik, Z. and Shand P. J. (2003): The effect of quantity and timing of brine addition on water binding and textural characteristics of cooked beef rolls. Meat Sci., 65: 771-778.

Purslow, P.P. (1985): The physical basis of meat texture: observations on the fracture behavior of cooked bovine *M. semitendinosus.* Meat sci., 12: 39.

Radhakrishna, K., Vijaya Rao, D., Jayathilakan, K., Dsouza Joyce., and Sharma, T. R. (1988): Studies on the freeze drying of rehydratable poultry product as large pieces. Ind. Food Packer., 42: 41-47.

Ranganna, S. (1986): Dehydrated fruits and vegetables in S. Ranganna (Eds.) Hand book of analysis and quality control for fruit and vegetable products (pp. 976-979). Tata McGraw-Hill Publishing Company Ltd. New Delhi.

Rao, K., Kowale, B., Babu, N. and Bisht, G. (1996): Effect of cooking and storage on lipid oxidation and development of cholesterol oxidation products in water buffalo meat. Meat Sci., 43 (2): 179-185.

Ratti, C. (2001): Hot air and freeze-drying of high-value foods – a review. J. Food Engg. 49: 311–319.

Ryan, K.N., Vardhanabhuti, B., Jaramillo, D.P., Van Zanten, J.H., Coupland, J.N., and Foegeding, E.A. (2012): Stability and mechanism of whey protein soluble aggregates thermally treated with salts. Food Hydrocolloids., 27 (2): 411–420.

Ruiz de Huidobro, F., Miguel, E., Blazquez, B. and Onega, E. (2005): A comparison between two methods (Warner-Bratzler and Texture Profile Analysis) for testing either raw meat or cooked meat. Meat Sci., 69: 527-536.

Shand, P.J. (2000): Textural, water holding and sensory properties of low fat pork bologna with normal or waxy strarch hull less barley. J. Food Sci., 65: 101-107.

Shiby, V.K. and Mishra, H.N. (2008): Modelling of acidification kinetics textural properties in buffalo milk curd (Indian Yoghurt). Intl. J. Dairy Technol., 61(3): 284-289.

Shultz, G.W., Russell, D.R. and Wierbicki, E. (1972): Effect of condensed phosphates on pH, swelling and water holding capacity of beef. J. Food Sci. 37: 860-864.

Smith, D.M., and Rose, A.J. (1995): Properties of Chicken salt soluble protein and whey protein concentrate gels as influenced by sodium tripolyphosphate. Poultry Sci., 74: 169-175.

Sogi, D. S., Shivhare, U. S., Garg, S. K. and Bawa, A. S. (2003): Water sorption isotherms and drying characteristics of tomato seeds. Biosystems Engg., 84(3), 297 - 301.

Taraldgis, B.G., Watts, B.M., Younathan, M.T. and Dugan, L.G. (1960): A distillation method for quantitative determination of malonaldehyde in rancid foods. J. Amer Oil Chem. Soc. 37: 44-48.

Templen, S.J., and Boxtel Van, A.J.B. (1999): Thin layer drying of black tea. J. Agric Engg. 74: 167-176.

Thomas, R., Anjaneyulu, A.S.R., and Kondaiah, N. (2008a): Natural antioxidants as hurdles to improve the quality of shelf stable pork sausages at ambient temperature storage. Fleiswirtschaft Int., 2: 81–86.

Tressler, D.K., Birdseye, C., and Murray, W.T. (1932): Tenderness of meat. Ind. Eng. chem., 24: 242-245.

Trout, G.R. and Schimidt, G.R. (1984): Effect of phosphate types and concentration, salt level and method of preparation of binding in restructured beef rolls. J. Food Sci., 49: 687-694.

Van Arsdel, B. S. and Copley, M. J. (1963): Food dehydration. NY, USA: Chapman & Hall.

Warner, K.F. (1928): Progress report of the mechanical test for tenderness of meat. Ann. Proc. Am. Soc., 21: 114-118.

Wierbicki, E., Howker, J.J., and Shultz, G. W. (1976): Effect of salt, phosphates and other curing ingredients on shrinkage of lean pork meat and the quality of smoked processed ham. J. Food. Sci., 41 (5): 1116-1121.