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Influence of temperatures and pretreatments on chicken meat during convective drying

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Abstract
Present studies were conducted to determine the influence of hot air drying on two types of chicken meat samples (raw and treated) having dimension approximately 1-cm long and 1-cm wide and 1-thick at five level of temperatures (45, 55, 65, 75, and 85 ^{0}C), air velocity (4.5 m/s). The effect of temperature was high on the kinetics of drying and quality of product as compared to treatment methods. Raw samples showed higher influence on volumetric shrinkage, rehydration ratio and hardness as compared with treated samples. Effective diffusivity was calculated from 6.335×10^{-09} to 3.195×10^{-08} (m^2/s) for treated samples and 5.920×10^{-09} to 2.986×10^{-08} (m^2/s) for raw samples. Activation energy was 36.79 KJ/mole for treated samples and 37.82 KJ /mole for raw samples.

Keywords: Chicken meat, rehydration ratio, hardness, effective diffusivity and volumetric shrinkage

Introduction

Due to increasing income of increasing population, the consumption of meat is estimated as 73% by 2050 [11]. The consumption of meat and product per year in developing countries is continuously increasing, from 10 kg per capita in 1960 to 26 kg per capita in 2000 and may be reach 36 kg per capita by 2030 [15]. Chicken meat is one of the most consumed worldwide with expected consumption of 94 million tonnes [2]. Chicken meat is rich in most of nutrients which are required by man. Chicken meat has higher value of protein content and all essential amino acids. Chicken meat has fat content in small amount. It is also rich in minerals and vitamins such as phosphorous, copper and iron in significant amount and thiamine, riboflavin and niacin in good amounts [5].

The drying is one most important unit operation for drying chicken meat with good quality and it is very cheap method for processed the meat or making shelf stable of chicken meat without need of refrigeration. The dehydrated chicken meat could be store for long time for future consumption by man. Meat drying offers advantages not only as a way of preservation however additionally helps to reduce packaging and transportation cost by reducing the load and volume. The dried meat product are often simply incorporated in food preparation additionally to sun drying, numerous technologies are often used to manufacture dried meats, like sun drying, hot air drying, freeze drying, superheated steam drying and microwave-assisted freeze drying [7, 31]. Meat Drying is to reduce the water content so microbes are unable to survive [35]. Chicken meat may be well-kept-up by drying or smoking, curing or processed into variety products such as sausage, chicken ham, nuggets, and patties etc [36]. Shelf life of chicken meat is very poor under normal atmospheric condition but it could be increased by storing in low temperature. In order to prolong the shelf life of chicken meat, there is need to store it in frozen storage but cost of frozen storage is very high and meat product can be spoiled after certain period of time. To overcome this problem, hot air drying is good option for drying of chicken meat with low cost and higher quality.

In present investigation, chicken breast meat was used for drying experiment because it has lower fat amount which is a better meat part of chicken for consumers. Studies were mainly carried out to investigate the effect of temperatures and pretreatment methods on drying kinetic and volumetric shrinkage, rehydration ratio, and hardness of breast meat of chicken.

Material and Methods

Samples preparation

Poultry birds were purchased from local market of Pantnagar, District Udham Singh Nagar, and U.K. The birds were slaughtered, dressed and eviscerated.

Manual slaughtering and deboning was done to obtain deboned breast meat for drying. During deboning process, only chicken breast meat were separated with help of the sharp knife. The obtained chicken breast meats were washed with clean water and kept in deep freezer until further processing. The initial moisture content of chicken meat sample was about 73 to 75 % (w.b.). During samples preparation, the skin of chicken breast meat was first removed and the flesh was then cut normal to the muscle fibers into three sample sizes of 1cm x1 cm x1cm.

Pretreatment of chicken meat sample

The chicken meat samples were pretreated with a solution containing 3.5% of sodium chloride only (raw sample) and other which were treated with solution of 3.5% of sodium chloride plus 0.015 % of sodium nitrite. The chicken meat samples for both pretreatments were dipping into solutions at 50°C for 10 minutes. The ratio of chicken meat to solution was 1:2 w/v [6, 8, 20]. After pretreatment, the chicken meat samples were removed from solution and spread on a screen to drain off the excess water. Pretreatment was carried out to avoid microbial growth and undesirable quality changes during hot air drying and storage period.

Drying process

For the drying purpose, a high velocity hot air dryer was used. A schematic diagram of experimental set up unit with its components is shown in Plate 1. The prepared samples were taken about 1 kg and equally spread on circular aluminum tray (size 460 mm diameter) and dried by radial diffusion. The drying experiments were accompanied at temperature of 45, 55, 65, 75 and 85 °C and air velocity of 5.5 for sample size of 1.0×1.0 ×1.0 cm, with three replication each. At the time of drying process, moisture loss was recorded in every 10 min intervals using a digital balance with accuracy of±0.001 g (Metteler, Germany).

Drying kinetic

Moisture content (MC)

The following method suggested by Ranganna [28] and IS-4626:1968 was used to determine the moisture content. In a flat bottom metallic dish, the powder of asbestos in form of thin layer was spread and dried in a hot oven under temperature of 110ºC for time of an hour. It was speedily enclosed and cooled in a desiccator and weighed (W_1). The sample of chicken meat was placed on thin layer of the asbestos and weighed as speedily as possible to avoid loss of moisture (W_2). The cover was detached and the samples of chicken meat were placed in hot air oven under temperature of 102±1ºC. The samples of chicken meat were dehydrated till two to three successive weights did not differ more than 5mg and final weight was noted (W_3). Now, moisture content was measured using the following formula:

Moisture content, % (d. b.)

$$= \frac{[(W_2 - W_1) - (W_3 - W_1)]}{(W_3 - W_1)} \times 100 \ \dots (1)$$

Moisture ratio (MR)

Moisture ratio was calculated using following equation and it could be defined as it is a ratio of average moisture content at given time to equilibrium moisture content and moisture content initially at zero time to equilibrium moisture content. Moisture ratio was dimensionless quantity.

$$MR = \frac{M - M_e}{M_o - M_e} \ \dots\dots\dots\dots (2)$$

Where, M= Average moisture content at time t, (%db)
M_e= Equilibrium moisture content (%db)
M_0= Moisture content (%db)at zero time.

Drying rate (DR)

Drying rate at drying time intervals was measured. Drying rate was calculated by following equation.

$$\frac{\partial M}{\partial t} = \ \dots . (3)$$

Where,
M_1 is Moisture content (%dry basis) at time t_1
M_2 is Moisture content (%dry basis) at time t_2
Δt is time difference

Diffusivity and activation energy analysis

Diffusivity

Fick's second law has been used for calculating the effective diffusivity [9]. It could be expressed as

$$\frac{\partial M}{\partial t} = Deff \frac{\partial^2 M}{\partial x^2} \ \dots\dots\dots . (4)$$

Where, M is moisture content (% dry basis), t is drying time (second), X is spatial dimension and Deff is effective diffusion coefficient (m^2/s)

$$MR = \frac{M - M_e}{M_0 - M_e} = \frac{8}{\pi^2}(e^{-\alpha_1 \beta} + \frac{1}{9}e^{-9\alpha_1 \beta} + \frac{1}{25}e^{-25\alpha_1 \beta} + \cdots . . (5)$$

Where β =Dt/S^2, Dimensionless, $\alpha_1 = \left(\frac{\pi}{2}\right)^2$
M= Average moisture content at time t,(%db)
M_e= Equilibrium moisture content (%db)
M_0= Moisture content at zero time
From equation 4 could be simplified as

$$MR = \frac{M}{M_i} = \frac{8}{\pi^2} \sum_{n}^{\infty} \frac{1}{(2n-1)^2} \exp\left\{-\frac{(2n-1)^2 \text{ Deff t}}{4L^2}\right\} \dots\dots (6)$$

Where, L=half the thickness of slab, n= positive integer
Now equation 5 was simplified by taking logarithm on both side when time drying was long.

$$\text{LnMR} = Ln \frac{8}{\pi^2} - \left(\frac{Deff\ t}{4L^2}\right) \dots\dots (7)$$

The diffusivity was estimated by plotting experimental drying data (MR) versus drying time and slope was calculated using equation 6. \

$$K_s = \frac{\pi^2 D}{4L^2} \ \dots . . (8)$$

Where Ks is slope of straight line obtain by calculating from equation 7.
Activation energy was calculated by solving following equation

$$D = D_0 \exp\left(-\frac{E_a}{RT_a}\right) \ \dots\dots\ (9)$$

Where E_a = the activation energy (kJ/mole)
R = universal gas constant (8.3143 kJ/mole)
T_a = absolute air temperature (K), and
D_0 = pre-exponential factor of the Arrhenius equation (m^2 /s).
The activation energy was calculated by plotting between logarithm of diffusion coefficient (lnDeff) and reciprocal of absolute temperature ($1/T_a$.). Slope was obtained from straight line then the activation energy was estimated by following equation

$$K_1 = \frac{E_a}{R} \quad \ldots\ldots(10)$$

Where, K_1= straight line slope

Hardness

Hardness of rehydrated chicken meat samples was measured by using texture analyzer (Model TA.HD Plus, Exponent Stable Microsystem, software version 3, 0, 5, 0). The specification of texture analyzer were 5 kg, 0.1 524 -524 mm and 0.01- 20 mm/s for load capacity, displacement, and speed respectively and the sample heavy duty platform was used. The probe was used to attach the probe to texture analyzer. In this study, AD/90 probe adapter was used to attach the probe to machine. The cylindrical probe coded by (P/75), it made of stainless steel. This probe was used in this experiments. The dehydrated chicken meat samples were rehydrated as per procedure of rehydration ratio was followed. After rehydration process, the rehydrated samples were subjected to texture analyzer profile test (TPA). Rehydrated sample was placed on center of heavy duty platform using the probe. Then compression test was started.in this study compression test was used.

Rehydration ratio

The evaluation of rehydration ratio was carried out according to Indian Standard (IS: 4624, 1968). One parts dehydrated chicken meat were cooked in ten parts of distilled water. Cooking was continued for 30 minutes and cooked sample was allowed to cool for 45 minutes. The beaker was covered with a watch glass having convex surface projecting inside and was inverted for about five minutes to drain off the excess water. This cooled, water drained material was then weighed and rehydration ratio was calculated as,

$$\text{Rehydration ratio} = \frac{WR}{WD} \quad \ldots\ldots(11)$$

Where, WR is weight of reconstituted dehydrated chicken meat sample, g.
WD is weight of dehydrated material before cooking.

Volumetric shrinkage

Volume metric shrinkage of chicken meat samples was measure as per method of Zogzas *et al.* [37]. Volumetric changes after drying and rehydration of the chicken meat samples was measured by liquid displacement method using liquid toluene having SG=0.860 at 20 ºC) as the medium using a measuring glass cylinder of 22 mm inside diameter and 50 ml capacity.

Results and Discussion

Drying Kinetic

Fig 1 to 2 Shows the plots of moisture content versus drying time at five drying temperatures (45,55,65,75 and 85°C) and air velocity(4.5 m/s). These drying graphs show the characteristic exponential dropping trend as it was found in many literatures of drying experiments for food products [10, 19, 34]. The initial moisture contents of the raw meat samples were found to be higher as compared to the treated meat samples. Which reduced faster during initial stage of drying as evident by steeper slope of drying curves, however, as the drying proceeded the slope of curves become flatter, indicating slower drying in raw meat as compare to treated meat. At air velocity, the drying occurred relatively faster with an increase in temperature of drying air. Chicken meat samples dried at higher air temperature presented slight higher removal of water during the first 30 min of drying [12, 22]. From figure 3 to 4 it was observed that moisture ratio was rapid decreased with faster rate in 30 minutes for drying of raw chicken meat sample as compare with treated meat sample. However, during the later stage of drying, moisture ratio was decreased with slower rate in treated sample. Drying was almost completed during falling rate period in both raw and treated samples.

Drying rates were evaluated from moisture content at successive time intervals. The drying rates at different drying time are shown in Fig. 5 to 6. Drying rates were increased when increased in temperature. Drying rate was found to be higher in treated sample than raw sample. Similar observations were reported by various researchers in drying of muscle food products such as Ortiz *et al.* [25] for fillet Fish, Luo *et al.* [21] for salted grass carp fillets, and Hu *et al.* [18] for meat.

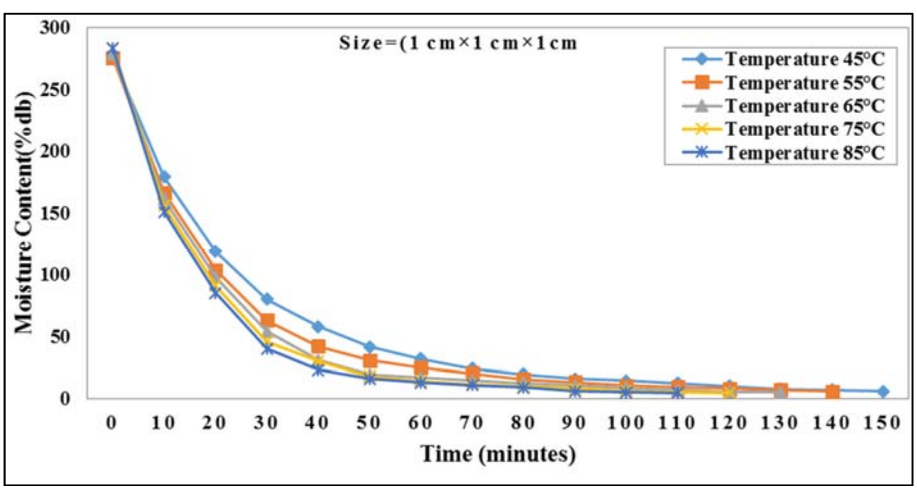

Fig 1: Changes in moisture content of treated chicken meat sample dried at 4.5 m/s of air velocity.

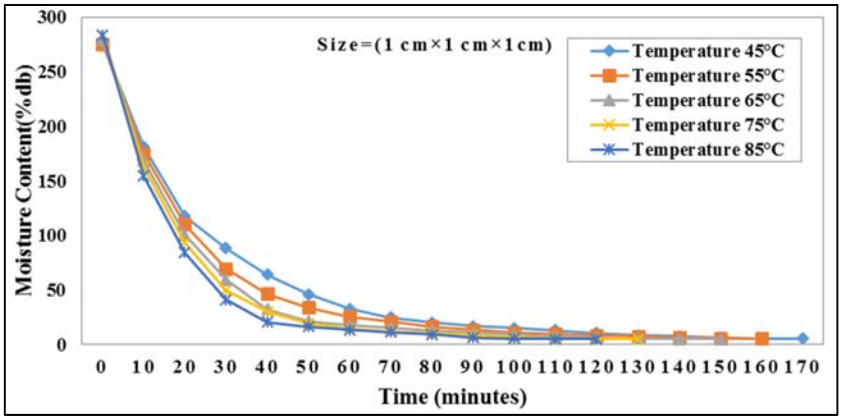

Fig 2: Changes in moisture content of raw chicken meat sample dried at 4.5 m/s of air velocity.

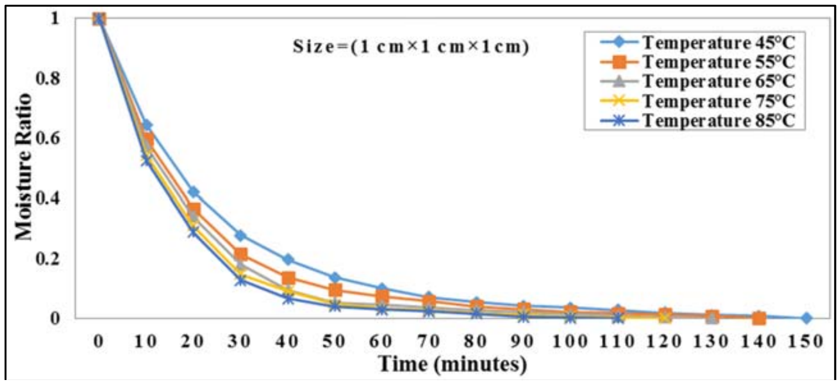

Fig 3: Changes in moisture ratio of treated chicken meat sample dried at 4.5 m/s of air velocity.

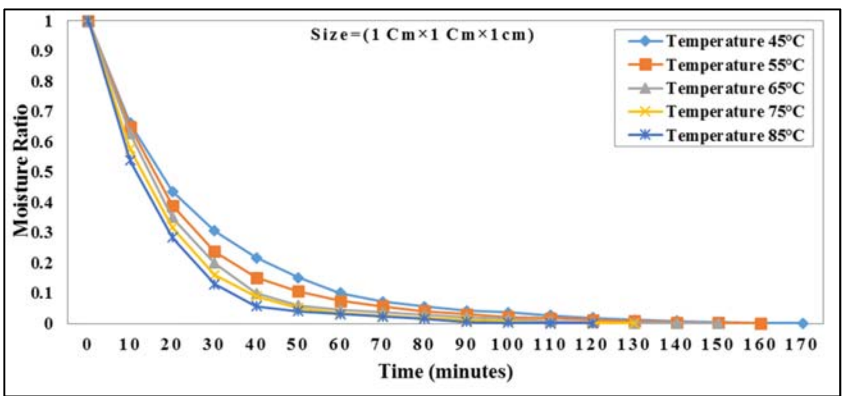

Fig 4: Changes in moisture ratio of raw chicken meat samples dried at 4.5 m/s of air velocity.

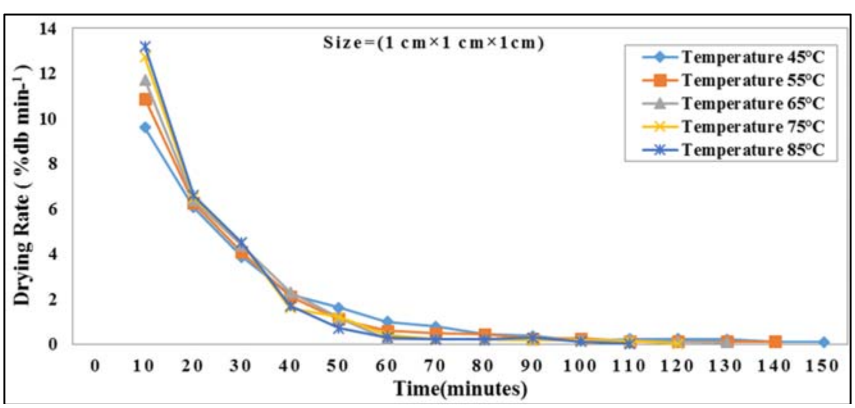

Fig 5: Changes in drying rate of treated chicken meat sample dried at 4.5 m/s of air velocity.

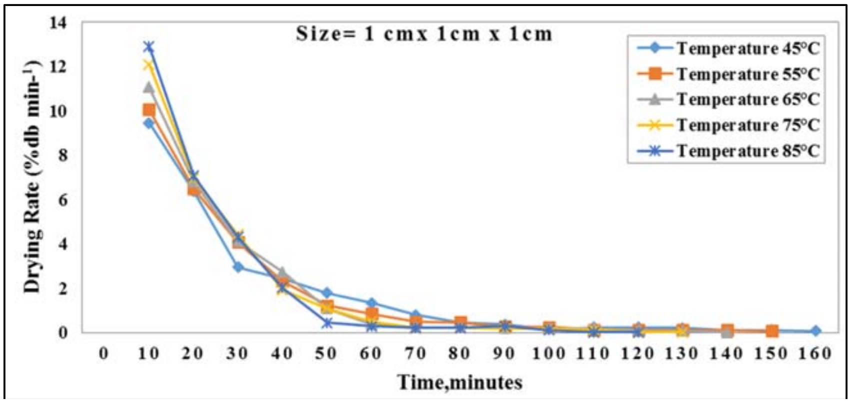

Fig 6: Changes in drying rate of raw chicken meat samples dried at 4.5 m/s air velocity.

Volumetric shrinkage

Volumetric shrinkage decreased when temperature was increased. The effect of temperature was highly significant in treated sample compared with raw sample. The insignificant product enlargement of the raw meat samples were observed at starting first hour of drying but this observation was not observed for the treated sample. Raw samples showed higher value of volumetric shrinkage (about 40.66-47.8%) compared with cooked samples (about 38.64 - 45.8 %). The minimum value of volumetric shrinkage was observed in the treated samples this may be due to sodium nitrite treatment. This similar observations were reported by Sa-adchom *et al* [31].

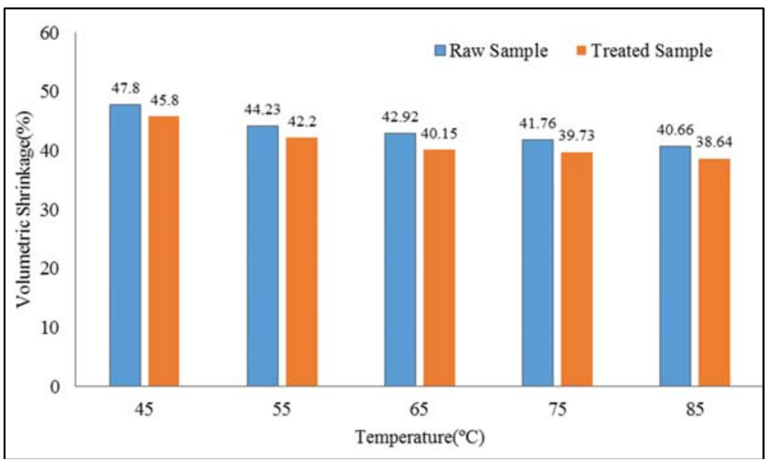

Fig 7: Effect on Volumetric shrinkage of two types of meat sample.

Rehydration Ratio

Rehydration is a process of moistening a dried product and that indicates quality criterion in many dried product. It is a display of cellular and structural breakdown that occurs during dehydration observed by Rastogi *et al.* [29]. For both raw and treated meat samples, rehydration ratio was decreased when temperature was increased. Rehydration ratio was lower when samples dried at high temperature than samples dried at a lower temperature. This similar observations were observed by Guo *et al.* [14]. Effect of temperature on rehydration ratio was found to be significant ($p < 0.05$) for both raw and treated samples dried at temperature of 45 °C as compared to those dried at temperature of 85 °C. This similar investigations were reported by Hii, C. L. *et al.* [16] and Narong *et al.* [24] for hot air drying of meat.

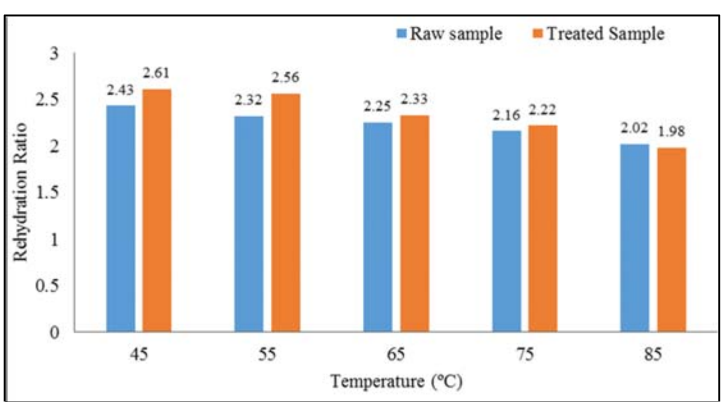

Fig 8: Effect on rehydration ratio of two types of meat sample.

Hardness

Hardness in both raw and treated chicken meat samples was significantly increased with increasing in temperature. Effect of temperature was observed significant ($p < 0.05$) during hot drying of both types of chicken meat samples. Although treated chicken meat samples had lower significantly ($p < 0.05$) in hardness than raw samples dried under same drying temperature. This could be due to salts and nitrite concentration in treated samples during drying. Effect of treatment on hardness of treated meat due to the separation of muscle piece caused the myofirillar protiens solubilization [17]. There was no significant difference ($p < 0.05$) was observed in raw samples while significant difference ($p < 0.05$) was observed at higher temperature (85 °C in raw samples. It was observed that in raw and treated samples, there was increment in hardness with increasing in temperature due to the extra dense arrangement of meat fibers made.

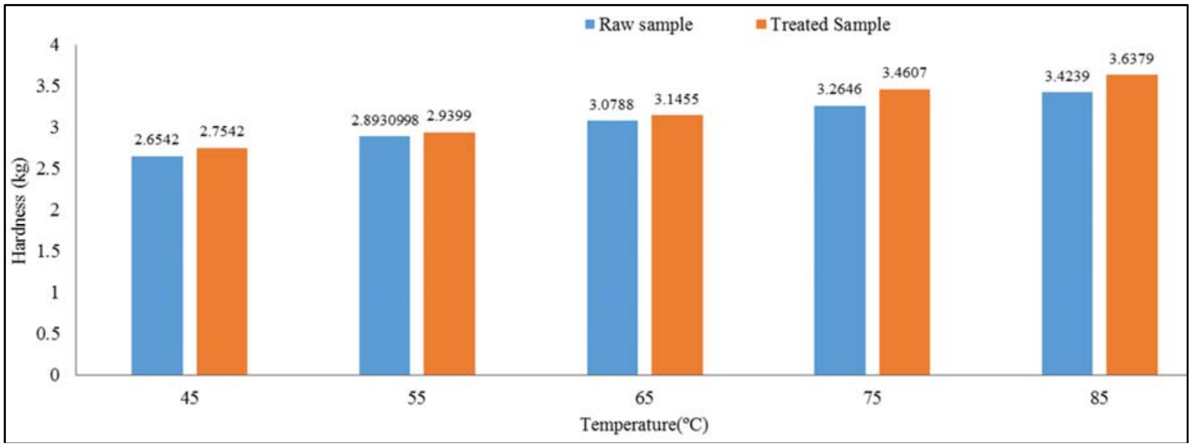

Fig 9: Effect on hardness of two types of meat sample.

Effective Diffusivity

Moisture diffusion is essential to predict the weight loss of meat products during heat and mass transfer process, which is quality concern in the dried meat product. Effective diffusivity (De) was calculated by using equation (5). The value of effective moisture diffusivity was varied from 6.335×10^{-09} (m^2/s) to 3.195×10^{-08} (m^2/s) for treated samples while it was varied from 5.920×10^{-09} (m^2/s) to 2.986×10^{-08} (m^2/s) for raw samples which is shown in Table 1. The highest value of effective moisture diffusivity was found at air temperature of 85 ^{0}C while lowest value of effective moisture diffusivity was calculated at air temperature of 45 ^{0}C in both types of meat samples Similar investigations about moisture diffusion in raw meat [33, 8, 30], meat treated with salts [13, 26] and meat products [23, 27] were reported by many researchers. They reported that values of moisture diffusivity have been changed because of product composition and drying conditions. It is clear that Table 1 shows values of effective moisture diffusivity increased with increasing in air temperature during drying the all types of meat samples [32, 1].

Figures 10 to 11 shows Arrhenius type relationship between effective diffusivity and temperature for both types meat samples. The equation (8) was used to calculate the activation energy. The logarithm of effective diffusivity (D_e) as the function of inversely of absolute temperature (T_{abs}) was plotted which resulting in Arrhenius type relationship between logarithm of effective diffusivity ($\ln D_e$) and reciprocal of absolute temperature ($1/T_{abs}$) for treated and raw samples. Activation energy was 36.79 KJ /mole and 37.82 KJ /mole for treated and raw samples respectively. For most of the food product, it was varied from 12.7 to 110 kJ/mol [37].

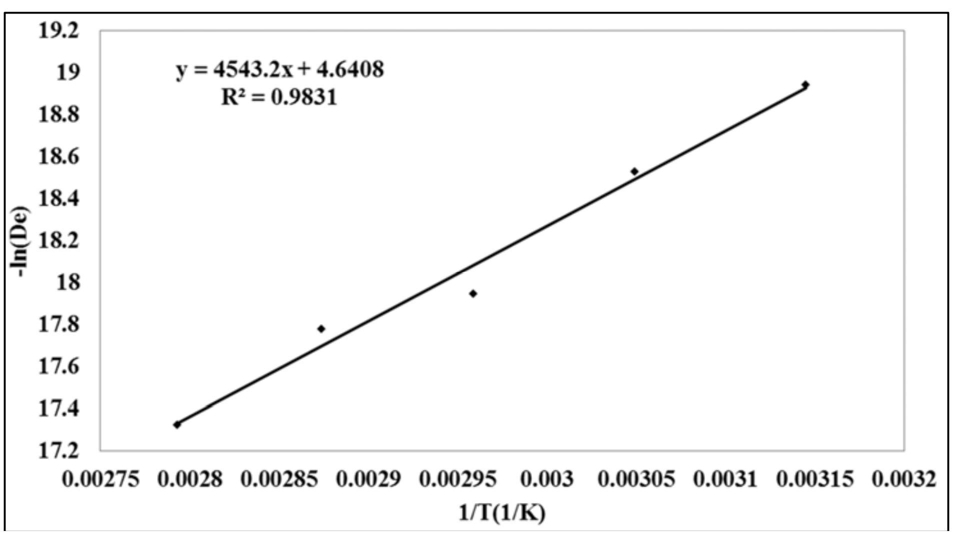

Fig 10: Arrhenius type relationship between effective diffusivity and temperature of raw samples.

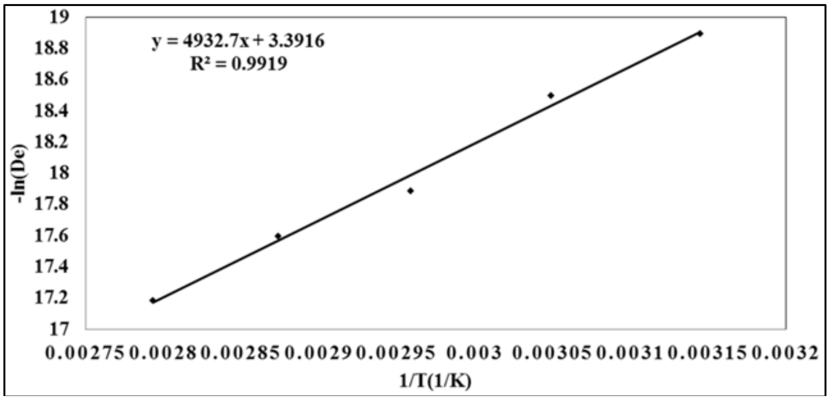

Fig 11: Arrhenius type relationship between effective diffusivity and temperature of treated samples

Table 1: Effective diffusivity of treated and raw chicken meat samples.

Type samples	Effective diffusivity(m^2/s)				
	45^0C	55^0C	$65\ ^0C$	75^0C	85^0C
Treated	6.335×10^{-09}	9.599×10^{-09}	1.719×10^{-08}	2.026×10^{-08}	3.195×10^{-08}
Raw	5.920×10^{-09}	8.971×10^{-09}	1.606×10^{-08}	1.894×10^{-08}	2.986×10^{-08}

Conclusion

The drying of treated samples was completed prior the raw samples this may be due to effect of sodium nitrite treatment. Drying of both raw and treated samples was observed during falling rate period. Arrhenius type temperature relationship was showed by effective diffusivity and both type samples were required a lower activation energy that shows a minimum energy required to activate moisture diffusion during drying. The samples dried at 45 °C showed a higher rehydration ratio as compared to that samples dried at 85 °C. Rehydration ratio was maximum in treated samples this may be due to nitrite treatment. Treated samples showed minimum hardness as compared to the raw samples.

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