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Research Article
Influence of Different Oven Drying Temperatures on Functional Properties and Amino Acid Composition of Eggs

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Abstract

Background and Objective: Egg as a source of protein is easily denatured by high temperature which affects its functional properties. The present study was aimed at evaluating the influence of different oven drying temperatures on functional properties of eggs. **Materials and Methods:** A total of 120 eggs were randomly assigned to four temperature treatments of three replicates and 10 eggs per replicate. The eggs were collected, broken, homogenized and were oven dried at four different temperatures of 35, 40, 45 and 50°C in a completely randomized design. Emulsifying activity (EA), foaming capacity (FC), foaming stability (FS), water absorption capacity (WAC), bulk density (BD), swelling capacity (SC), oil absorption capacity (OAC) and amino acid were evaluated. Data were subjected to Analysis of Variance at $\alpha_{0.05}$. **Results:** The EA was higher ($p<0.05$) at 40 and 45°C compared to 35°C. The FS at 35, 40 and 45°C were similar ($p>0.05$) but lower than at 50°C, FC (26.47±1.41%) and WAC (56.34) were higher ($p<0.05$) at 50°C than in other treatments. The OAC and BD were higher ($p<0.05$) at 35°C while SC (1.49±0.03%) was lower ($p<0.05$) at 45°C compared to other treatments. Amino acid score however was higher ($p<0.05$) for eggs oven dried at 40°C compared to other treatments. **Conclusion:** Functional properties were better at 50°C while the amino acid score was minimally affected at 40°C.

Key words: Emulsifying activity, swelling capacity, bulk density, functional properties of eggs, oil absorption capacity

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Eggs are one of nature's most complete foods containing high quality protein, vitamins and minerals[1] and have been an important part of the human diet as they have traditionally been used for breakfast, home meal preparation, baking and as ingredient in many foods. They supplied a large amount of complete, high quality protein (which contains all essential amino acids for humans). They are also one of the least expensive single-food sources of complete protein[2]. The quality of eggs starts to decline as soon as they are laid by hens. Although factors associated with the management and feeding of hens can play a role in internal egg quality, but egg handling and storage practices also have a significant impact on the quality of eggs reaching consumers. Since egg is perishable due to its high moisture content, the external environment of egg during storage plays a huge role in determining its quality. It was earlier reported that eggs are best stored at refrigerated temperature. Erratic power supply and fluctuations in environmental temperature however are major challenges to egg storage in the tropical environment[3,4]. Improper storage of eggs affects the internal quality of egg especially albumen height and Haugh unit which are significant factors in the egg processing industry[5]. Egg processing involving the application of heat may be a suitable alternative to improve the keeping quality of egg by reducing to a minimal the moisture content (dehydration) thus preventing spoilage[6]. Dehydration is an interesting method of preserving egg components for several reasons as transport and storage of dried egg products is less costly and requires less space[6]. Also, at low moisture content egg products are less susceptible to microbial growth and the uniformity and easy dosage of dried egg products make them an ideal ingredient in the food industry[7]. High temperature however denatures proteins in egg and may consequently affect the functional properties of egg which is of utmost importance to the food processing industry as several processing and preservation methods like spray drying, tray drying and freeze drying techniques have been adopted with repercussions on the qualities of the products[8]. The properties of eggs are very delicate and the final quality of the dried product can be significantly affected by drying conditions[7]. The main roles of functional properties of whole egg are stabilization of emulsion, foamability and buildup of firm gels. Whole egg is also used as colorant[9]. These natural properties of whole egg are useful in bakery foods, bakery mixes, mayonnaise and salad dressings, confections, ice cream, pastas and many convenience foods[9]. Egg processors are concerned about these temperature treatments because the products should not only be microbiologically safe but should also perform satisfactorily[10]. Heat treatments are often employed to ensure egg products safety and improved shelf-life. However, high heat treatment has detrimental effects on the functional properties of egg proteins and amino acids which end up in commercially undesirable finished products[11]. Since heat treatment plays a major role in egg processing and safety, it is therefore imperative to identify the best oven drying temperature that would preserve the functional and nutritional qualities of egg. This study was therefore aimed at evaluating the effects of different oven drying temperatures on the functional properties and amino acid score of eggs.

MATERIALS AND METHODS

The experiment was carried out at the Animal Products and Processing Laboratory and Animal Nutrition Laboratory of the Department of Animal Science, University of Ibadan, Nigeria. The study lasted 3 weeks and was conducted between the months of October and November, 2017.

Preparation of whole egg samples: A total of 120 eggs obtained from Bovan brown laying hens aged 62 weeks were randomly assigned to 4 temperature treatments of three replicates and 10 eggs per replicate. The eggs were collected, broken, homogenized and spread in flat containers and thereafter were oven dried at four different temperatures of 35, 40, 45 and 50°C till constant weights were attained. The egg flakes were scooped, ground into powder, sieved with a 60 mm mesh and then weighed into different plastic containers for further investigation. Data obtained were on Emulsifying activity (EA), foaming capacity (FC), foaming stability (FS), water absorption capacity (WAC), bulk density (BD), swelling capacity (SC), oil absorption capacity (OAC) and amino acid score.

Functional properties

Emulsifying activity: The emulsion activity was determined by the method of Yasumatsu *et al.*[12]. The ratio of the height of the emulsion layer to the total height of the mixture was calculated as the emulsion activity expressed in percentage:

$$\text{EA} = \frac{\text{Height of the emulsified layer}}{\text{Height of the total amount of content in the tube}} \times 100$$

Foaming stability: Foaming capacity and stability were determined according to the method reported by Coffmann and Garcia[13]:

$$\text{Foaming capacity} = \frac{\text{Volume after whipping-Volume before whipping (mL)}}{\text{Volume before whipping (mL)}} \times 100$$

$$\text{Foaming stability} = \frac{\text{Volume after standing-Volume before standing (mL)}}{\text{Volume before standing (mL)}} \times 100$$

Swelling capacity: One gram of egg powder sample was weighed into 100 mL conical shaken and 15 mL distilled water was added. The mixture was shake for 15 min at low speed on a stirrer and transferred into a hot water bath and heated for 40 min between 80-85°C with constant stirring. The heated mixture was transferred to a pre-weighed centrifuge tube and 7.5 mL distilled water was added and centrifuged at 2200 rpm for 20 min. The supernatant was carefully decanted and cooled in a desiccator. The precipitate with the centrifuge tube was weighed:

$$\text{Swelling capacity} = \frac{\text{Weight of the centrifuge containing sample before drying}}{\text{Weight of the centrifuge containing sample after drying}}$$

Water and oil absorption capacity: Water absorption capacity (WAC) and oil absorption capacity (OAC) were determined using the method described by Sefa-Dedeh and Agyir-Sackey[14]. The water and oil absorption capacity was expressed as a percentage of the initial sample weight. The determination was done in triplicate:

$$\text{WAC/OAC} = \frac{\text{Hydrated residue weight-Dry residue weight}}{\text{Dry residue weight}}$$

Water and oil retention capacity: The water and oil retention capacities were determined by the method of Sosulski and McCurdy[15]. Water and oil retention capacity was expressed as percentage of water and oil bound per gram of the sample:

$$\text{WRC/ORC} = \frac{\text{Residue hydrated weight after centrifugation-Residue dry weight}}{\text{Residue dry weight}}$$

Bulk density: Bulk density was determined by using the method described[16]. Ten grams of each sample was weighed (W1) into a 25 mL graduated measuring cylinder. The sample was gently tapped to eliminate space between the egg powder and reweighed (W2). The study was conducted in three duplicate:

$$\text{Bulk density (g mL}^{-1}) = \frac{\text{W1-W2}}{\text{Volume of sample before tapping}}$$

Where:
W1 = Weight of sample before tapping
W2 = Weight of sample after tapping

Amino acid determination: Essential amino acids were determined by the spectrophotometric method using ninhydrin chemical reaction according to Moore and Stein[17]. Percentage amino acid was calculated using the equation:

$$\text{Amino acid (\%)} = \frac{\text{Absorbance of sample} \times \text{Gradient factor} \times \text{Dilution factor}}{10{,}000}$$

Statistical analysis: Data were subjected to descriptive statistics and one way analysis of variance at $\alpha_{0.05}$ using SAS[18] and means were separated using Duncan's multiple range test of the same software.

RESULTS

Functional properties of egg: The results obtained were significantly different ($p<0.05$) indicating that the oven drying temperatures had effect on the functional properties of the dried egg components (Table 1).

Table 1: Functional properties of oven drying eggs at different temperature

Parameters	35°C	40°C	45°C	50°C	SEM
Emulsifying activity (%)	40.83^{b}	46.25^{a}	45.00^{a}	43.75^{ab}	0.78
Foaming capacity (%)	20.59^{b}	19.61^{b}	13.73^{c}	26.47^{a}	1.41
Foaming stability (%)	6.86^{c}	11.76^{b}	8.82^{bc}	20.59^{a}	1.63
Swelling capacity (%)	1.28^{b}	1.25^{b}	1.49^{a}	1.32^{b}	0.03
Water absorption capacity (%)	32.68^{b}	24.39^{b}	25.49^{b}	56.34^{a}	4.12
Oil absorption capacity (%)	37.44^{a}	34.02^{bc}	35.61^{b}	33.54^{c}	0.51
Bulk density (g mL^{-1})	0.78^{a}	0.63^{b}	0.55^{b}	0.50^{b}	0.03

^{a,b,c}Means across rows with different superscripts differ significantly at $p<0.05$

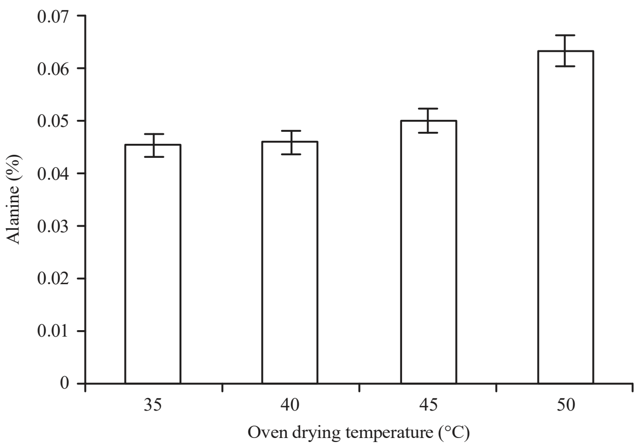

Fig. 1: Effect of egg drying temperature on alanine

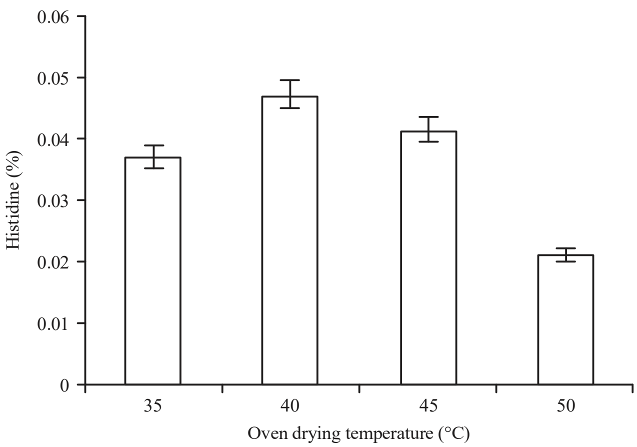

Fig. 2: Effect of egg drying temperature on histidine

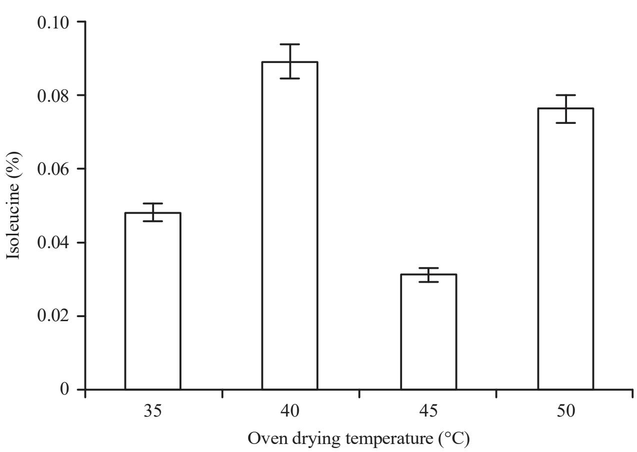

Fig. 3: Effect of egg drying temperature on isoleucine

Emulsifying activity (EA) 46.25 in this study was significantly higher ($p<0.05$) in eggs dried at 40°C compared

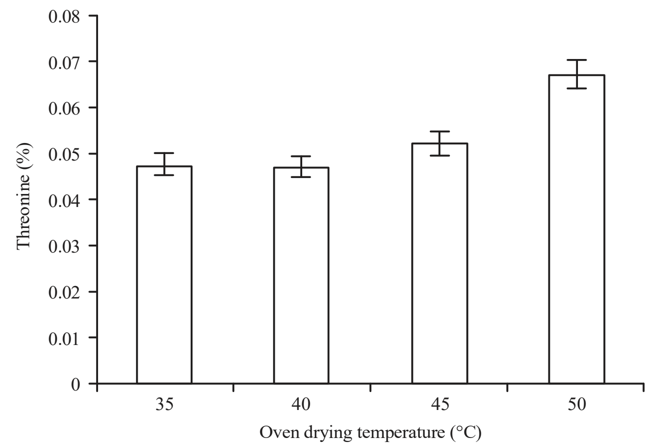

Fig. 4: Effect of egg drying temperature on threonine

to 40.83 in eggs dried at 35°C but was not significantly different ($p>0.05$) from EA of eggs dried at 45 and 50°C (45.00 and 43.75), respectively. The foaming capacity of eggs dried at 35 and 40°C (20.59 and 19.61) were similar ($p>0.05$) but different from 13.73 and 26.47 in eggs dried at 45 and 50°C, respectively. Foaming capacity (26.47) of eggs dried at oven temperature of 50°C however; was significantly higher ($p<0.05$) than for every other oven drying temperatures. Similarly, foaming stability of eggs at 50°C (20.59) was significantly higher ($p<0.05$) than 6.86, 11.76 and 8.82 in eggs dried at 35, 40 and 45°C, respectively. Observation from this study showed that swelling capacity (1.49) of eggs dried at 45°C was higher ($p<0.05$) than 1.28, 1.25 and 1.32 in those dried at 35, 40 and 50°C. Water absorption capacity (56.34) of eggs dried at 50°C was higher than 32.68, 24.39 and 25.49 in eggs dried at 35, 40 and 45°C, respectively while oil absorption capacity (37.44) of eggs dried at 35°C were higher than 34.02, 35.61, 33.54 in eggs dried at 40, 45 and 50°C. The bulk density of eggs dried at 35°C (0.78) was higher ($p<0.05$) than 0.63, 0.55 and 0.50 in eggs dried at 40, 45 and 50°C, respectively.

Amino acid profile of eggs subjected to different oven drying temperatures: The effect of oven drying temperature on amino acids composition of egg is shown in Fig. 1-12. Alanine composition (0.063%) was higher at 50°C (Fig. 1) while histidine (0.048%) and isoleucine (0.089%) compositions were higher at 40°C (Fig. 2 and 3). Threonine content (Fig. 4) of the egg (0.067%) was higher at 50°C while lysine (0.082) and tryptophan (0.033) compositions were higher at 40°C compared to other oven drying temperatures (Fig. 5 and 6, respectively). Composition of methionine (0.18%) and valine

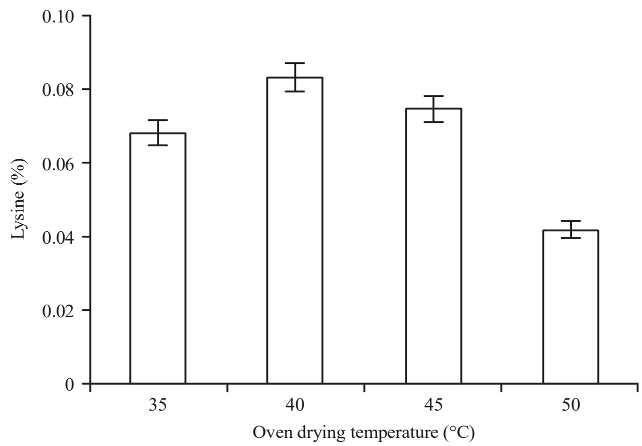

Fig. 5: Effect of egg drying temperature on lysine

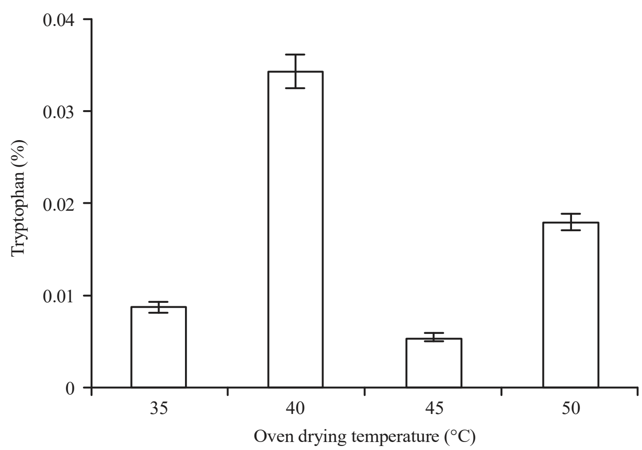

Fig. 6: Effect of egg drying temperature on tryptophan

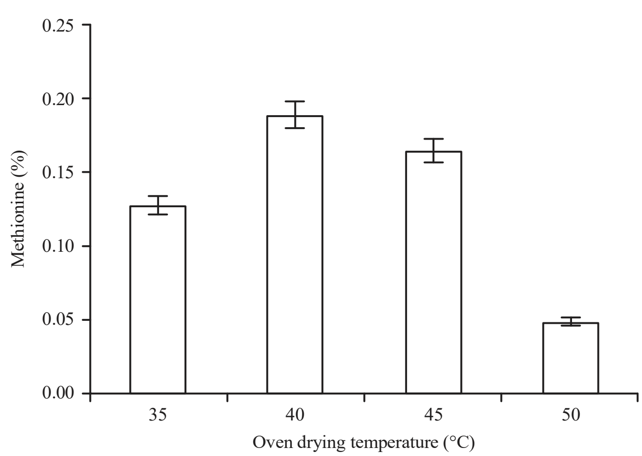

Fig. 7: Effect of egg drying temperature on methionine

(0.11%) contents of the egg were higher at 40°C (Fig. 7 and 8) but cysteine content (0.068) was higher at 50°C (Fig. 9).

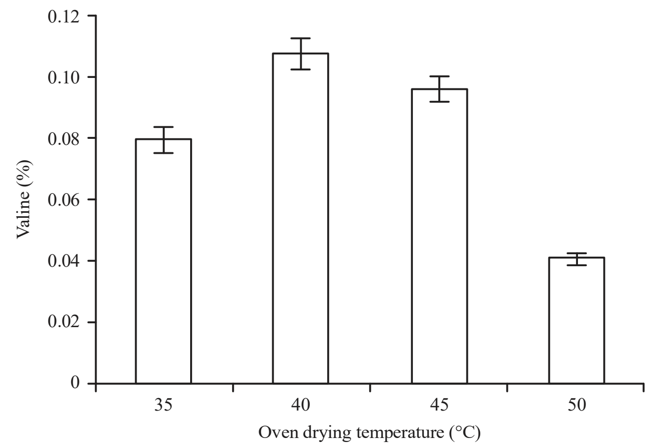

Fig. 8: Effect of egg drying temperature on valine

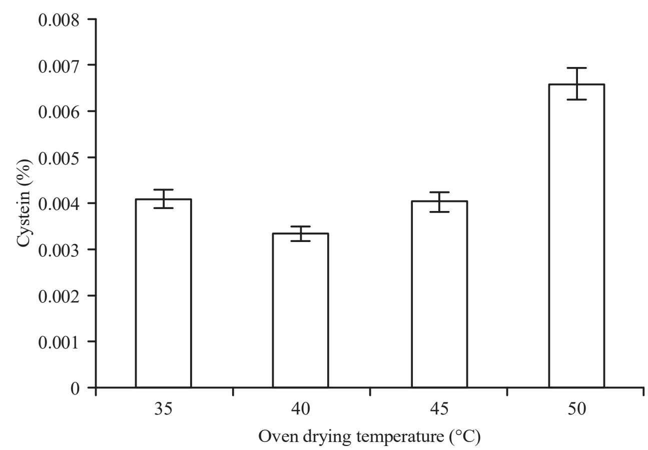

Fig. 9: Effect of egg drying temperature on cysteine

Leucine content (0.06%) of the egg (Fig. 10) and phenylalanine content (0.056%) of the eggs were higher at 50 and 40°C (Fig. 11). The total amino score of eggs subjected to different oven drying methods is shown in Fig. 12. Eggs oven dried at 40°C had the highest amino acid score followed by those dried at 45, 35 and 50°C.

DISCUSSION

Functional properties of foods determine the application and use of such food materials as ingredients for the production of various food products[19,20]. The EA of 40.83-46.25% reported in this study was lower than 55% reported by Ndife *et al.*[21]. Emulsifying properties can be evaluated by the protein's emulsion stability (ES) and emulsion activity (EA)[22]. The ES is a measure of the stability of the emulsion over a certain time span and EA is a measurement of

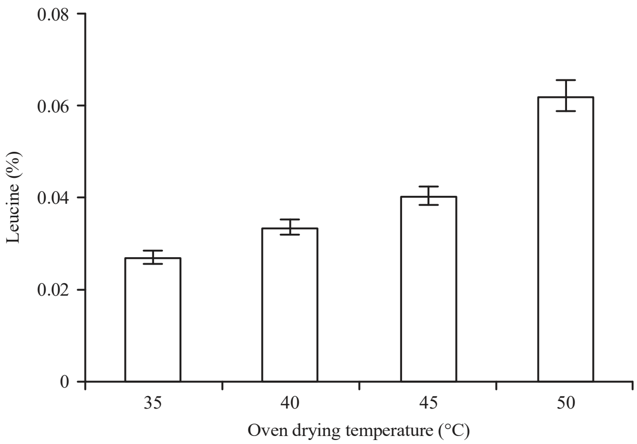

Fig. 10: Effect of egg drying temperature on leucine

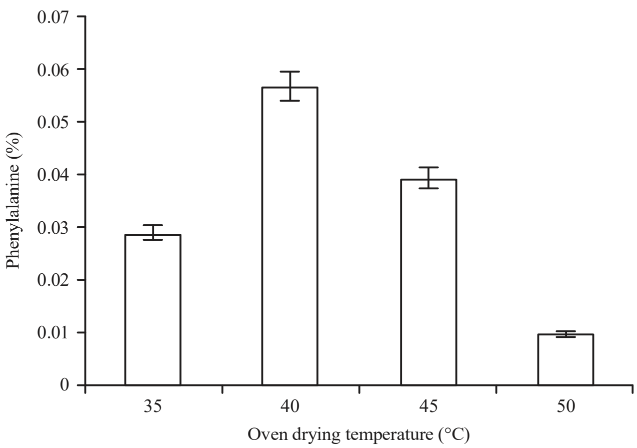

Fig. 11: Effect of egg drying temperature on phenylalanine

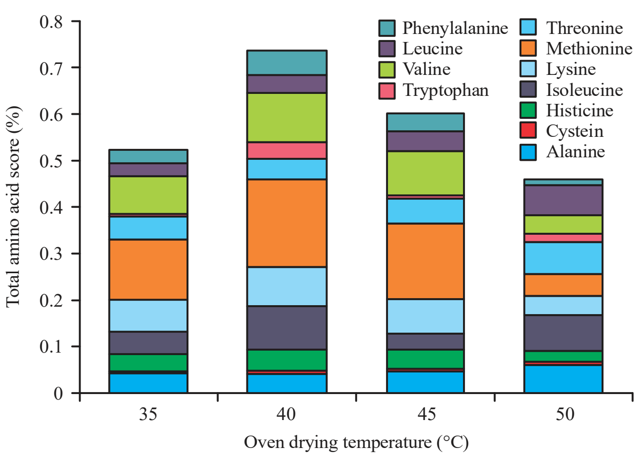

Fig. 12: Total amino acid score for different dried-eggs

how much oil a protein can emulsify per unit protein[23]. Increased foaming capacity and stability reported in this study at 50°C could be due to the effect of heat on lipid component of the egg as density of yolk lipid would reduce due to heat application. Also the increase might also be associated with the dissociation of ovomucin-albumin complex with heat treatment. Foaming properties of proteins are usually evaluated by aeration characterization, i.e., foaming capacity and foam stability[24,25]. Even though air is incorporated during foaming, aeration is only achieved by a stable network capable of retaining the air bubbles in the foam system. Egg albumen has excellent food foaming properties. Such properties are determined by the ability to rapidly adsorb on the air-liquid interface during whipping or bubbling and by its ability to form a cohesive visco-elastic film by way of intermolecular interactions[26]. When whole egg is beaten, air bubbles are trapped in the liquid albumen and the foam is formed. The foam is defined as a colloidal dispersion in which a gaseous phase is dispersed in liquid or solid phase. Excessive whipping of the protein solution produces a higher concentration of smaller bubbles resulting in more unstable foams. This instability depends on the decrease in the bubble elasticity resulting from excessive in solubilisation of proteins at the air-albumen interface[27]. Although foaming ability and capacity of egg is a function of the albumen components. However, the influence of egg yolk on the foaming properties of egg white has been discussed[9,27-29] as the presence of even small quantities of yolk decreases the albumen foaming ability[28]. The detrimental influence of yolk on albumen can be explained by the formation of a complex of a yolk component with ovomucin[30]. Heat treatment however is beneficial for the foaming properties of egg white containing yolk as it is responsible for the dissociation of this complex[31]. Stadelman and Cotterill[9] reported that the foaming stability of egg is affected by drying process and conditions. It was reported that in the early stage of production of dried eggs, the egg powder when reconstituted and whipped at room temperature seldom gave foam sufficiently stable to produce acceptable sponge cakes[32]. Earlier research however, reported improved foaming properties under room temperature as formation is quicker and foam volume is greater[30]. When egg white was heated in a dry state (7.5% moisture) at 80°C for 10 days, it was found that the foaming power and foam stability increased almost fourfold without an associated loss of the solubility[29]. The authors revealed that the heating of dried egg white in the dry state caused a substantial increase in its molecular flexibility and surface hydrophobicity, faster unfolding and greater intermolecular interaction at the interface forming a more cohesive film[33].

Swelling capacity is an important factor used in determining the amount of water that diets would absorb and the degree of swelling within a given time[34]. The swelling capacity was higher at 1.49% for eggs dried at 45°C compared to other oven drying temperatures. This implied that the ability of the egg powder to absorb water will depreciate beyond drying temperature of 45°C.

Water and oil absorption values are properties that exert some useful influence on the rheological, functional and baking qualities of their products[35,36]. The water absorption capacity is an index of the maximum amount of water that a food product would absorb and retain[35,37]. The reduction in the oil absorption capacity of the dried eggs could be as a result of the increase in temperature that must have affected the lipid constituent of the products. Potter and Hotchkiss[8] reported that these properties of eggs help to retain moisture and oil during baking and subsequent storage and thus enhance both the physical and sensory qualities of their products. In addition, Giami and Bekebain[38] reported that food products with low water absorption capacity had reduced microbial activities and since WAC of eggs dried at 50°C was lower than those dried at other lower temperatures, it could be implied that shelf-life of egg products dried at higher temperature will be increased and also safety will be enhanced.

The consistency of energy density (energy per unit volume) of the food and the frequency of feeding are also important in determining the extent to which an individual will meet his or her energy and nutrient requirements[39]. The bulk density value is of importance in packaging[40]. There was a reduction in bulk density with increasing oven drying temperature, thus implying that less quantity of the food samples would be packaged in constant volume thereby ensuring an economical packaging. Packed bulk densities would ensure more quantities of the food samples being packaged, but less economical[22]. According to Osundahunsi and Aworh[41], nutritionally loose bulk density products enhance digestibility especially among children with weak digestive system. Alanine, threonine, cysteine, leucine contents were higher at 50°C compared to other oven drying temperatures while histidine, lysine, methionine, isoleucine, tryptophan, valine and phenylalanine were higher at 40°C. Eggs are rich in all the essential amino acids that are useful for the body which includes histidine, leucine, lysine, isoleucine, threonine, tryptophan, methionine, phenylalanine and valine. Because the essential amino acids in egg protein have the same pattern as the pattern of amino acids needed by the human body it is often utilized as a standard of comparison for determining the quality of protein with other foods[42].

Eggs dried at an oven temperature of 40°C retained a much higher total amino acid profile compared to other oven drying temperatures (Fig. 12). Observations from this study with respect to amino acid scores were however within the range reported by Coultate[43] for amino acid profile of eggs. Oven drying temperature of 50°C is recommended for food as processing activity that revolves around the functionality of eggs and egg products while 40°C is recommended for processing activities targeted at retaining to a considerable extent the nutrient profile of egg and its products.

CONCLUSION

Functional properties of eggs dried at 50°C were better than other oven drying temperatures used in this study while eggs dried at an oven temperature of 40°C retained a much higher total amino acid profile compared to other oven drying temperatures.

SIGNIFICANCE STATEMENT

This study has provided information on the best egg drying temperature that can be beneficial to the egg and food processing industry. Also, this study will give an insight into assisting researchers to uncover critical areas of dry egg technology that are yet to be explored.

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