

Comparative quality attributes and sensory acceptance of deep-fried and oven-cooked broiler chicken nuggets

Olayemi Rashidat AWODOYIN* and Ayomide Esther FASE

Department of Animal Science, University of Ibadan, Ibadan, Oyo State, Nigeria.

*Corresponding author. Email: olayemiawodoyin@gmail.com; Tel: +2340827290842.

Copyright © 2024 Awodoyin and Fase. This article remains permanently open access under the terms of the [Creative Commons Attribution License 4.0](https://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Received 24th January 2024; Accepted 24th February 2024

ABSTRACT: The growing concern over consumption of fatty foods had increased the focus on formulating and developing nutritious and tasty low-fat meat products. However, the cooking methods employed during preparation of a food can change consumer's perception about the product. Breast and thigh muscles were deboned, grounded, mixed with nugget ingredients to form an emulsion, and then divided into two. Each part was deep-fried or oven-cooked after cutting into nugget pieces (3.5 cm diameter, 1.5 cm thickness, 20.5 g weight). Yield (%), moisture (%), organoleptic characteristics (9 point hedonic scale), cholesterol (%), phenol (mgGAE/100g), were assessed on fresh while Thiobarbituric Acid Reactive Substances (TBARS $\mu\text{g MDA/Kg}$) and Total Viable Counts (TVC cfu/g) were observed at 0, 7, 14 days of storage. Data were analysed using T-test and factorial analysis @ $\alpha = 0.05$. Oven cooked nuggets yield (90.43) and moisture (55.84) were significantly higher (Pr $t < 0.05$) than 79.94 (yield) and 52.39 (moisture) deep fried nuggets. No significant differences (Pr $t > 0.05$) in colour, aroma, tenderness and overall acceptability were observed in both nuggets. Flavour (6.00) and juiciness (5.00) of oven-cooked nuggets are significantly higher (Pr $t < 0.05$) than 4.83 (flavour) and 3.17 (juiciness) of deep-fried nuggets. Cholesterol (62.74) and phenol (176.12) contents of deep-fried nuggets were higher (Pr $t < 0.05$) than 55.72 (cholesterol) and 144.53 (phenol) of oven cooked nuggets. Oven-cooked nuggets TBARS (2.44, 2.69, 4.21) were significantly higher ($p < 0.05$) than 2.18, 2.41, 3.96 in deep-fried nuggets at 0, 7 and 14 days respectively. Oven-cooked TVC at 0 (2.50), 7 (4.51) and 14 (5.98) days were significantly higher ($p < 0.05$) than 2.10, 4.09 and 5.62 of deep-fried nuggets at 0, 7 and 14 days respectively. The high yield and organoleptic scores elucidated that oven-cooked nuggets are well accepted and this method can be used in the preparation of chicken nuggets.

Keywords: Deep frying, oven cooking, product yield, sensory assessment, storage quality.

INTRODUCTION

Heating or cooking of food is carried out in order to make food soft and easily digestible (Parvin *et al.*, 2020) and frying is one of the cooking techniques where fat or oil is utilized as the medium of heat transfer with direct contact with the food (Vittadini *et al.*, 2005). The simultaneous heat and mass transfer of oil and air promote a number of changes, such as moisture loss and oil uptake (Mir-Bel *et al.*, 2012) and consumers are becoming more health conscious of the foods they consume (Sharima-Abdullah *et al.*, 2018). As much as consumers want food that is convenience, sweet, tasteful and shelf stable, they also

demand for food that is low in fat and calories (Sharima-Abdullah *et al.*, 2018). This is due to the health implications associated with consumption of food containing high proportion of these nutritional qualities.

Food products are usually developed to provide convenience and also satisfy consumer demands for colour, taste and value (Mazza, 2000). However, the cooking temperature and time were crucial for the edible quality of food, and also different cooking conditions or methods could affect the extent of chemical reactions and the physical properties (Reid *et al.*, 2016). Furthermore,

different cooking methods employed in the preparation of food products can change the perception of consumers toward a product because of the significant impact it might have on eating quality (Resurreccion, 2003). For instance, organoleptic properties such as colour, texture, palatability and tenderness of meat and meat products are greatly affected by the type of cooking methods (Pietrasik *et al.*, 2005). Besides this, it could also change the nutritional value, freshness, flavour and juiciness of meat thus resulting in varied perceptions by consumers (Hoffman and Wiklund, 2006). This is because consumer acceptance for cooked meat products is determined mainly by the flavour, which is influenced by different cooking methods and storage conditions (Parvin *et al.*, 2020). These methods might also induce a significant changes in their chemical composition (Miglio *et al.*, 2008) which will invariably result in different concentration and bioavailability of bioactive compounds of the product (Miglio *et al.*, 2008) i.e. heating or cooking influences the rate of lipid peroxidation in meat and meat products (Akinwumi and Olagoke, 2019). Thus, the need to evolve food production processes that will provide not only convenience, high organoleptic qualities, health and nutritional benefits, but also shelf stability of the product.

Nugget is a favorite fried meat product that is consume as fast food all over the world (El-Anany *et al.*, 2020; Parvin *et al.*, 2020). It is usually prepared by deep frying method which is one of the most common cooking methods of chicken meat (Hwang *et al.*, 2011). The development of value-added product such as chicken nuggets is one of the best ways to increase poultry meat consumption (Yogesh *et al.*, 2013). However, the eating qualities of meat are significantly affected by the type of cooking methods (Pathare *et al.*, 2016).

Therefore, the current study was conducted to access the effect of two different cooking methods viz oven cooking and deep frying on the proximate composition, phenol contents, sensory characteristics and keeping qualities (thiobarbituric reactive substances levels and bacterial quality) of broiler chicken nuggets.

MATERIALS AND METHODS

Processing of chicken nuggets

The broiler chicken used in the current study was purchased from the Teaching and Research Farm, University of Ibadan. The production of chicken nuggets was carried out in a fully equipped and sanitized Animal Products and Processing Laboratory in the Department of Animal Science, University of Ibadan. The chicken nugget samples were prepared following the procedure of Arshad *et al.* (2017) with slight modification. The broiler was euthanized, cut into primal cuts and the quality determined (pH 6.1, moisture 75.82±0.14%, crude protein 15.28±0.04%,

Table 1. Composition of ingredients used in nugget preparation.

Ingredients composition	Quantity (%)
Chicken meat	72.00
Pepper	3.00
Wheat flour	10.00
Refined salt	1.50
Ice water	8.00
Fresh garlic	0.50
Fresh onions	5.00
Total	100.00

Garlic and onions in paste form weight/weight.

ash 1.66±0.03%, ether extract 2.44±0.09%, crude fibre 5.79±0.04%). The breast and thigh muscle were removed, deboned and cut into chunks, and then ground using an electrical mincer (Electric meat grinder, model KNG762, Kenwood) with 5 mm plate. The minced chicken meat was mixed with the ingredient (Table 1) using a meat mincer until a homogenous mixture was obtained. The emulsion was then divided into two equal parts. Each portion (separately) was weighed and formed into nuggets pieces and each nugget was approximately 3.5 cm diameter, 1.5 cm thickness with average weight of 20.5 g. The formulated nuggets were pre-dusted (with wheat flour), batter-coated and breaded (with dried bread crumbs). Each portion of the breaded nuggets was subjected to the two cooking methods: deep-frying and convection oven heat.

Deep frying

The oil (Grand soya oil®) was first pre-heated to 180°C and the chicken nuggets were deep-fried for 7 minutes. Fried nuggets were drained on absorbent paper towels and allowed to cool down to room temperature (27°C).

Oven cooking

Convection oven (electrical oven) was used to cook the nugget. The oven was first pre-heated to a temperature of 220°C. The raw nugget samples were laid on the oven tray and allowed to cook for 20 minutes but turned intermittently every 5 minutes interval. After cooking, the nuggets samples were spread on a clean tray and allowed to cool quickly to room temperature.

A probe thermometer was used to record the internal cooked temperatures (72°C) of the products by inserting a probe thermometer into the centre of each nugget. Preliminary trials for time and temperature combination were conducted to determine the length of cooking time required to reach the designated internal temperature.

In preparing both nuggets, hygienic practices were applied during the preparation, packaging and storage processes of the chicken nugget products. The chicken nugget samples used for sensory evaluation were removed (after determining the cooking yield) and kept separately while the remaining were packed in polyethylene Ziploc bags and stored at refrigerated temperature for further analysis.

Experimental design

In a completely randomized design, nuggets were prepared from two methods of cooking viz: deep frying and oven cooking. Each type of cooking methods was replicated three times.

Parameters assessed on chicken nuggets

Cooking yield

The effect of cooking on cooking yield of chicken nuggets was determined using standard procedures. The cooking yield was determined as reported by Naveena *et al.* (2006) as follows:

Cooking Yield (%) = (Weight of cooked nuggets-Weight of raw nuggets) x100

Sensory assessment

The sensory evaluation was carried out immediately after cooling to ensure there are no negative impacts on the organoleptic properties of the developed product. The nugget samples were prepared by slicing cooked nugget to 2-3 cm² size, blind-coded with specific random numbers and served to the panelists in random order. The assessment was carried out by a 20-member untrained panel of judges of both genders drawn from undergraduates and postgraduate students of the Department of Animal Science, University of Ibadan. Panelists were instructed to cleanse their palates between samples using cracker biscuits and water. Each cooked chicken nugget was evaluated for colour, aroma, flavour, juiciness, tenderness and overall acceptability on a 9-point hedonic scale (1=extremely dislike and 9=extremely like) (Fernandez-Lopez *et al.*, 2006).

Proximate composition determination

This was carried out according to the procedures outlined by AOAC (2019). The parameters accessed were moisture, ash, crude protein and fat.

Cholesterol, total phenol and total volatile basic nitrogen (TVB-N) of chicken nuggets

Nuggets cholesterol contents were determined according to the procedures described by Turhan *et al.* (2007). The cholesterol concentration was expressed as mg/100g, dry weight basis of nugget samples.

The antioxidant status of the chicken nuggets was determined by measuring the total phenolic contents (TPC) (%) in the nugget. The TPC was determined following the procedure described by Senevirathne *et al.* (2006) and it was estimated as gallic acid equivalent (mg GAE/100 g).

The total volatile base nitrogen (TVBN) was measured using a macro-Kjeldahl distillation according to the method of Kearsley *et al.* (1983) and expressed as mg/100 g sample.

Lipid oxidation

Chicken nugget samples were evaluated for thiobarbituric acid reactive substances (TBARS) following the method described by Liu *et al.* (2010) and the results were expressed as micrograms of malonaldehyde per kilogram of chicken nugget ($\mu\text{g MDA/Kg sample}$). The samples were assessed on 0, 7 and 14 days of storage period

Microbiology analysis

Microbiological profile of the chicken nuggets was determined by methods described by APHA (1984). Readymade media were used for each microbial analysis. The microbes assessed were total viable count (TVC), total coliform count (TCC), total fungi count (TFC), total staphylococcus counts (TSC) and total pseudomonas counts (TPC). Ten grams of sample was weighed into a pre-sterilized mortar and pestle and mixed properly with 90 mL of 0.1% sterile peptone water. Serial dilutions (10-fold) were made with peptone water (0.1%). Preparation of sample and serial dilutions were carried out by observing all possible aseptic conditions. The colonies formed were observed, counted and average number of colonies were multiplied by the reciprocal of the dilution and expressed as log₁₀ colony forming units (cfu)/g of sample.

Statistical analysis

Data for all parameter were collected in triplicates, data was analysed using T-test and factorial analysis procedure of SAS version 9.2 (2014) at $\alpha = 0.05$. T-test was used in assessing the sensory, proximate composition, phenol, cholesterol and TVB-N while completely randomized

design in a 2 x 3 factorial arrangement was used in assessing the TBARS and microbial load considering the two cooking methods and days of storage as factors to be considered.

RESULTS AND DISCUSSION

Sensory characteristics of deep fired and oven cooked chicken nuggets

Displayed on Table 2 is the sensory characteristics of deep fried and oven cooked nuggets. The colour (6.67; 7.17), aroma (4.33; 4.50), tenderness (5.00; 4.17) and overall acceptability (6.85; 6.83) were not significantly different ($p > 0.05$) from each other. Oven cooked nugget flavour (6.00) and juiciness (5.00) was significantly higher ($P < 0.05$) than 4.83 (flavour) and 3.17 (juiciness) of deep-fried nuggets.

Eating quality is one of the parameters that influence consumer acceptance of meat (Pathare and Roskilly 2016) and various eating quality attributes such as colour, flavour, tenderness and juiciness are affected by cooking hence the need for sensory assessment of meat products. This study showed that not all the sensory parameters assessed on the nuggets were affected by the different cooking methods. For instance, colour which is a vital quality indicator that determine the consumption or rejection of meat product (Hwang *et al.*, 2011; da Silva *et al.*, 2019) as well as the first sensory indicator of consumer expectation of the overall quality of a product (Chonpracha *et al.*, 2020) and aroma which encourage an initial evaluation of the taste expected by the customers remain statistically unchangeable in all the nuggets. The results of the sensory characteristics further showed that the mean score of colour of both deep fried and oven cooked nugget samples were highly acceptable (above 6) while that of aroma were higher than 4 (neither liked nor disliked) (9-point hedonic). Due to the transfer of oil into the product which usually occurs during deep frying, it is assumed that some sensory characteristics such as flavour and colour will be enhanced in the final fried products (Hwang *et al.*, 2011). It is therefore expected that the deep-fried nugget will have higher palatability. Contrarily, the panelist ratings showed a higher preference score in the flavour of oven cooked nuggets. The enhanced flavour rating of the oven cooked nuggets by the panelist could be as a result of the high cooking temperature which the nuggets were subjected to during cooking because the oven high temperature was reported to be a contributing factor to colour and flavour enhancement of oven cooked meat (Rinaldi *et al.*, 2010). This high oven temperature was also reported to cause a reduction in tenderness and juiciness of oven cooked meat (Rinaldi *et al.*, 2010) but contrarily, in this present study, juiciness scores were significantly higher in oven cooked chicken nugget. This might be as a

result of the high moisture content of the oven cooked nugget (Table 2) because juiciness in cooked nuggets is the amount of moisture or juice perceived during mastication (Hayes, 2009). This moisture is assumed to have provided a mouth feel sensation that initiate better consumption of the nugget thus its acceptability by the panelist. In addition, the low moisture content of the deep-fried nugget implied a high-water loss and in sensory assessment of meat a high-water loss indicate that such meat will be less juicy (Bertram *et al.*, 2003) thus the low juiciness rating of deep-fried nuggets by the panelists.

Furthermore, both nuggets remained in the positive zone of acceptance but the panelists were indifferent in the overall impression (overall acceptability). The panelist indifference in the overall acceptability of both products may be attributed to the fact that there was no significant difference in the crude fat content of both nuggets. This is because reduction in fat can significantly affect the acceptability of a product (Lukman *et al.*, 2009) as fat is a major and an important factor that contributes to sensory characteristics such as palatability (flavour, juiciness and mouth feel) thus influencing the acceptability of meat products (Akoh, 1998; Yogesh *et al.*, 2013).

Proximate composition of oven cooked and deep-fried chicken nuggets

The proximate composition (Table 3) showed that the moisture content (%) (55.84) of oven cooked nugget is significantly higher ($P < 0.05$) than 52.39 recorded in deep fried nuggets. Crude protein (%) (19.75; 21.62), ash (%) (0.91; 1.24) and crude fat (%) (3.44; 3.77) of both nuggets were not significantly different ($p > 0.05$). The yield (%) (90.43) obtained from oven cooked nugget was statistically higher ($P < 0.05$) than 79.94 recorded in deep fried nugget.

The most significant factors for consumer acceptability of chicken nuggets are the physicochemical characteristics and proximate composition (Lukman *et al.*, 2009) thus the need to accessed the proximate composition and cooking yields of the differently processed chicken nuggets. Cooking loss is an important meat quality attribute and thermal treatments of meat causes water loss (Lorenzo and Domínguez, 2014). The high moisture loss (low moisture) recorded in fried chicken nugget could be attributed to the simultaneous heat and mass transfer of oil and air which usually promote numerous chemical changes such as moisture loss (Mir-Bel *et al.*, 2012). The increase in frying oil temperature also contributed to the increased moisture loss (Innawong *et al.*, 2006) of the deep-fried chicken nuggets. The high moisture content of oven cooked nugget is attributed to the slow rate of water evaporation from the product caused by presence of steam in the oven chamber (Clausen and Ovesen, 2005) thus making the product to retain more

Table 2. Sensory characteristics of oven and deep fried cooked chicken nuggets.

Parameters	Cooking methods		SEM	p-value
	Oven cooked	Deep fried		
Colour	6.67±1.03	7.17±0.75	0.45	0.36
Aroma	4.33±1.51	4.50±1.64	0.79	0.86
Flavour	6.00±0.63 ^a	4.83±0.75 ^b	0.35	0.02
Tenderness	5.00±1.90	4.17±1.17	0.79	0.38
Juiciness	5.00±1.26 ^a	3.17±1.47 ^b	0.69	0.04
Overall Acceptability	6.85±2.23	6.83±1.47	0.94	1.00

^{a,b}: means in the same rows with similar superscripts are not statistically different (p<0.05).

Table 3. Cooking yield and proximate composition of oven-cooked and deep-fried nuggets.

Parameters (%)	Cooking methods		SEM	p-value
	Oven cooked	Deep fried		
Moisture	55.84±0.92 ^a	52.39±0.25 ^b	0.41	0.0004
Crude protein	19.75±1.31	21.62±1.79	0.78	0.1422
Ash	0.91±0.89	1.24±0.27	0.09	0.0552
Crude fat	3.44±0.15	3.77±0.20	0.05	0.1271
Cooking Yield	90.43±1.18 ^a	79.94±2.11 ^b	0.86	0.0001

^{a,b}: means in the same rows with different superscripts are statistically different (p<0.05).

Table 4. Cholesterol, phenol and total volatile basic nitrogen of differently cooked nuggets.

Parameters	Cooking methods		SEM	p-value
	Oven cooked	Deep fried		
Cholesterol (%)	55.72±0.83 ^b	62.74±2.88 ^a	1.06	0.0030
Phenol (mg GAE/100 g)	144.53±2.24 ^b	176.12±2.61 ^a	1.22	<0.0001
TVB-N (mg/100g)	21.18±0.29	21.25±1.50	0.54	0.9275

^{a,b}: means in the same rows with similar superscripts are not statistically different (p<0.05).

water at the end of the cooking time. Thus, the different cooking yields recorded in both chicken nuggets produced in this study. The crude protein of the nuggets produced in this study is higher than 12.52-16.62% while the moisture content falls within 34.71-56.51% and the ash contents of deep-fried nuggets were slightly above 1.20-1.58% recorded for Malaysian commercial chicken nugget (Lukman *et al.*, 2009). The crude protein however falls with the range of 16.9 to 23.3% recorded by Fathy-Eman (2012) but lower than 22 to 25% reported by Jackson *et al.* (2009). It is expected that the fat content of deep-fried chicken nuggets would increase because as moisture in meat is replaced with oil i.e. oil absorption occurs (Saguy and Pintus, 1995) but contrarily, the fat content of both nuggets did not differ. The differences in the proximate composition recorded by the authors especially the protein is a reflection of the protein content of the different raw meat used in the manufacturing of the chicken nuggets (Cáceres *et al.*, 2006).

Cholesterol, phenol and total volatile basic nitrogen of oven cooked and deep-fried nuggets

As shown on Table 4, the cholesterol (%) (55.72) and phenol (mg GAE/100 g) (144.53) contents of oven cooked nuggets were statistically lower (Pr t <0.05) compared with 62.74 (cholesterol) and 176.12 (phenol) obtained in deep fried nuggets. No significant differences (Pr t >0.05) in the total volatile nitrogen-base TVN-B (mg/100g) of oven-cooked (21.18) and deep fried (21.25) nuggets.

There was significant variation in the parameters of total cholesterol and phenols of the nugget samples obtained through different cooking methods. The differences in phenolic concentration in the nugget samples might be attributed to the different degree of heat treatment they were subjected because the types of cooking process can either cause damage to the active constituents or increase the content of bioactive compounds (Miglio *et al.*, 2008; Mena-García *et al.*, 2021). Also, most of the phenolic

Table 5. Thiobarbituric acid reactive substances levels of oven-cooked and deep-fried nuggets during 14 days of storage.

Storage days	Cooking methods TBARS ($\mu\text{g MDA/Kg}$)		SEM	p-value
	Oven cooked	Deep fried		
0	2.44 \pm 0.07 ^a	2.18 \pm 0.06 ^b	0.03	0.002
7	2.69 \pm 0.06 ^a	2.41 \pm 0.08 ^b	0.04	0.001
14	4.21 \pm 0.10 ^a	3.96 \pm 0.11 ^b	0.05	0.014

^{a,b}means in the same rows with similar superscripts are not statistically different ($p < 0.05$). **Key:** TBARS= Thiobarbituric reactive substances.

Table 6. Main effect of cooking methods on thiobarbituric reactive substances levels and storage days of chicken nuggets.

Parameters	Cooking methods						Pr>(F)
	0 storage days		7 storage days		14 storage days		
	Oven cooked	Deep fried	Oven cooked	Deep fried	Oven cooked	Deep fried	
TBARS ($\mu\text{g MDA/Kg}$)	2.435 ^d	2.180 ^e	2.405 ^d	2.690 ^c	4.205 ^a	3.960 ^b	0.8751

^{a,b,c,d}means in the same rows with different superscripts are statistically different ($Pr < 0.05$). **Key:** TBARS= Thiobarbituric reactive substances.

compounds are relatively unstable when subjected to heat and a significant amount of it is lost during high heat treatment (Abd Ghani *et al.*, 2023). Although the TVB-N levels recorded in the chicken nuggets from both cooking methods were similar, but they were slightly above (15-20 mg) as recommended by the Egyptian Standard (E.S. "Egyptian Standard" No.1651, 2005) for chilled rabbit meat cooked by different cooking methods.

Thiobarbituric acid reactive substances of oven cooked and deep-fried chicken nuggets over storage period

Thiobarbituric Acid Reactive Substances (TBARS) ($\mu\text{gMDA/g}$) (Table 5) obtained in oven cooked at 0 (2.44), 7 (2.69) and 14 (4.21) days of storage are significantly higher ($Pr < 0.5$) than 2.18, 2.41 and 3.96 recorded in deep fried nuggets on 0, 7 and 14 days of storage respectively. The effect of cooking methods on storage and levels of TBARS (Table 6) showed that the TBARS levels in oven-cooked nuggets on days 0 (2.435) and 7(2.405) were similar ($Pr > 0.05$) but significantly higher ($Pr < 0.05$) than 2.180 recorded in deep-fried nuggets at day 0 and 2.690 recorded on day 7 while the levels (4.205) in oven-cooked nuggets at day 14 was higher ($Pr < 0.05$) than 3.960 in deep fried nuggets on the same day.

In all the products, TBARS values increased significantly with the advancement in storage period. Statistical analysis showed that the TBARS content of the product are significantly affected by the different thermal treatment. It is assumed/expected that the deep-fried chicken nugget would be high in TBARS due to the presence of oil in the nugget which is absorbed during

frying which would have aided the rate of lipid oxidation in the product. But in contrast, irrespective of the storage days the oven cooked chicken nugget had higher TBARS values. Although the main effect of cooking methods on storage days and TBARS levels showed that on day 7 the TBARS levels of the deep-fried chicken nugget were lower but as at the 14th day of storage, the TBARS of oven-cooked nuggets were higher. This high TBARS in oven-cooked nuggets might probably be due to the high oven temperature the oven-cooked nuggets subjected to. This is because continuous high temperature during cooking increases the generation of reactive oxygen species such as free radicals and non-radicals and these consequently strengthen the tendency of protein and lipid oxidation (Traore *et al.*, 2012). Although the deep-fried nugget also passed through high temperature but for a shorter time (7 minutes) compared with the duration of exposure of oven cooked nuggets (20 minutes). This is because duration of exposure to higher temperature is also an important factor that contributes to oxidation in food. Longer time and lower temperature are more affected than a shorter time and higher temperature (Broncano *et al.*, 2009; Lorenzo and Domínguez 2014) thus the reduced TBARS recorded in deep fried chicken nuggets. The results of this study further proved that oxidation processes during cooking are more affected by cooking time than temperature (Lorenzo and Domínguez, 2014). The high TBARS of the oven cooked nugget could also be attributed to its low phenolic contents (Table 4) at the end of the cooking procedure. This further showed that the bioavailability and antioxidative activity of bioactive compounds are significantly affected by different cooking/heating process (Miglio *et al.*, 2008). The observation in this study also agrees with Pathera *et al.* (2016) who reported a significant increase

Table 7. Microbiology quality of oven-cooked and deep-fried nuggets over 14 days of storage.

Storage days	Microbial counts (cfu/g)	Cooking Methods		SEM	p-value
		Oven-cooked	Deep-fried		
0	TVC ($\times 10^5$)	2.50 \pm 0.13 ^a	2.10 \pm 0.11 ^b	0.06	0.002
	TCC ($\times 10^2$)	1.05 \pm 0.04 ^b	1.17 \pm 0.04 ^a	0.02	0.006
	TFC ($\times 10^3$)	1.19 \pm 0.04	1.11 \pm 0.05	0.02	0.068
	TSC ($\times 10^3$)	1.17 \pm 0.05 ^a	1.05 \pm 0.06 ^b	0.03	0.022
	TPC ($\times 10^1$)	1.16 \pm 0.02 ^a	1.08 \pm 0.03 ^b	0.01	0.003
7	TVC ($\times 10^5$)	3.09 \pm 0.07 ^a	3.51 \pm 0.08 ^b	0.04	0.002
	TCC ($\times 10^2$)	1.17 \pm 0.03 ^b	1.67 \pm 0.07 ^a	0.03	0.04
	TFC ($\times 10^3$)	1.51 \pm 0.06	1.48 \pm 0.02	0.05	0.72
	TSC ($\times 10^3$)	1.34 \pm 0.07 ^a	1.21 \pm 0.04 ^b	0.03	0.002
	TPC ($\times 10^1$)	1.31 \pm 0.03 ^a	1.14 \pm 0.03 ^b	0.03	0.006
14	TVC ($\times 10^5$)	3.62 \pm 0.06 ^a	3.98 \pm 0.10 ^b	0.04	0.006
	TCC ($\times 10^2$)	1.72 \pm 0.06	1.75 \pm 0.08	0.03	0.121
	TFC ($\times 10^3$)	1.93 \pm 0.17	1.98 \pm 0.09	0.07	0.650
	TSC ($\times 10^3$)	1.51 \pm 0.06 ^a	1.32 \pm 0.08 ^b	0.03	0.004
	TPC ($\times 10^1$)	1.82 \pm 0.04	2.08 \pm 0.58	0.21	0.404

^{a,b}means in the same rows with different superscripts are statistically different ($P < 0.05$). **Key:** TVC = Total Viable Counts, TCC = Total Coliform Count, TFC = Total Fungi Counts, TSC = Total Staphylococcus Counts, TPC = Total Pseudomonas Counts.

in TBARS of oven cooked nugget when compared with steamed cooked nuggets. Lorenzo and Domínguez (2014) also reported a similar trend with roasted, grilled and microwaved foal meat having higher TBARS compared with deep fried foal meat. The TBARS values obtained in this study were lower than 0.23-0.55mgMDA/kg reported by Hwang *et al.* (2011). The higher TBARS levels of oven cooked nuggets implied that its oxidative stability is lower compared with deep fried nuggets which will result in reduced storage time.

Microbiological quality of oven cooked and deep-fried chicken nuggets of over a storage period

The microbial quality (cfu/g) as presented on Table 7, the TFC in either of the cooking methods irrespective of the storage days are not statistically different ($p > 0.05$) while the TCC and pseudomonas in both nuggets at day 14 did not differ ($p > 0.05$) from each other. The TVC and staphylococcus recorded in oven cooked nuggets were significantly higher ($p < 0.05$) than that of fried nuggets irrespective of the number of storage days while the TCC in oven cooked nuggets on 0 and 7th days were significantly high ($p < 0.05$).

The effect of cooking methods and storage days on microbial load as displayed (Table 8) showed that the TVC on days 7 (4.510) and 14 (5.987) found in deep-fried nuggets were significantly higher ($p < 0.05$) than 4.085 and 5.620 recorded in oven-cooked nuggets while at day 0, the

TVC (4.498) of oven cooked nuggets were higher ($p < 0.05$) than 2.055 recorded in deep-fried nuggets.

Irrespective of the cooking method, the TCC (1.050; 1.170), (1.570; 1.673), (3.115; 3.203), TFC (1.185; 1.113), (1.508; 1.483), (3.032; 2.985) and TPC (1.158; 1.078), (1.308; 1.135), (2.815; 3.075) load on each storage days of 0, 7 and 14 days respectively were not significantly different ($p > 0.05$) from each other. The TSC on days 0 (2.170; 2.052) and 14 (4.135; 3.807) were not significantly different ($p > 0.05$) while on day 7, TSC (2.517) in oven-cooked nuggets were significantly higher ($p < 0.05$) than 2.305 found in deep fried nuggets.

The study showed that the cooking methods did not have any influence on the counts of TCC, TFC and TPC (expressed as cfu/g) in the nuggets on each storage days implying that proliferation of these microbes is not dependent of either the methods of cooking or the storage days. This is in agreement with the report of Pathera *et al.* (2016) who opined that microbiological quality of nuggets were not affected by methods of cooking and also Yadav *et al.* (2016) with chicken sausage and Cholan *et al.* (2011) who reported no significant difference in total bacterial count (cfu/g) of meat balls. The results of this study further elucidated that microbiological quality with respect to the counts of TVC and TSC of the nuggets were significantly affected by the two methods of cooking during the 14 days of cold storage at $4 \pm 2^\circ\text{C}$. Also, these microbes (TVC and TSC) were high in oven cooked nuggets irrespective of the days of storage. This result is in agreement with Bhat *et al.* (2013) and Yavas and Bilgin (2010) who reported

Table 8. The main effect of the cooking methods and storage days on microbial quality of chicken nuggets.

Microbes (cfu/g)	Cooking methods						P>F
	0 storage days		7 storage days		14 storage days		
	Oven cooked	Deep fried	Oven cooked	Deep fried	Oven cooked	Deep fried	
TVC (x10 ⁵)	2.498 ^e	2.055 ^f	4.085 ^d	4.510 ^c	5.620 ^b	5.987 ^a	0.7072
TCC (x10 ²)	1.050 ^c	1.170 ^c	1.570 ^b	1.673 ^b	3.115 ^a	3.203 ^a	0.8465
TFC (x10 ³)	1.185 ^c	1.113 ^c	1.508 ^b	1.483 ^b	3.032 ^a	2.985 ^a	0.8958
TSC (x10 ³)	2.170 ^e	2.052 ^e	2.517 ^c	2.305 ^d	4.135 ^a	3.807 ^b	0.0083
TPC (x10 ¹)	1.158 ^b	1.078 ^b	1.308 ^b	1.135 ^b	2.815 ^a	3.075 ^a	0.1921

^{a,b,c,d,e,f}: means in the same rows with different superscripts are statistically different (Pr t<0.05). **Key:** TVC = Total Viable Counts, TCC = Total Coliform Count, TFC = Total Fungi Counts, TSC = Total Staphylococcus Counts, TPC = Total Pseudomonas Counts.

similar increase in microbial counts during refrigerated storage period of chicken meat nuggets, chicken meat balls and patties respectively. The values obtained in this study for TVC were below 6.11-6.42 cfu/g (standard counts) reported by Pathera *et al.* (2016) for chicken nuggets after 20 days of refrigerated storage. Furthermore, the microbial quality of both nuggets in terms of TVC did not exceed 10⁴ recommended by the EOSQC (2005) for total bacterial counts in meat products.

Conclusion

Consumer acceptability of chicken nugget is mostly dependent on its nutritional composition and only those nuggets with high nutritional value and good sensorial characteristics will be the favourite choice of consumers. During frying, moisture in meat was replaced with the frying oil thus increased palatability (juiciness) but with the probability of the product fat to be increase, thus the tendency of consuming more fat through deep fried nugget. However, this effect was eliminated in oven cooked nuggets and this improvement on the product quality will further widen the acceptability of oven-cooked chicken nuggets. Conclusively, this study had shown that cooking chicken nugget through conventional oven although relatively less shelf stable with respect to the high level of thiobarbituric acid reactive substances within the experimental storage period, but did not adversely affect the nutritional quality, organoleptic properties and its acceptability by the consumers.

CONFLICT OF INTEREST

The authors declare that they have no conflict interest.

REFERENCES

Abd Ghani, A., Abd Rashid, N.Y., Abd Razak, D. L., Jamaluddin, A., Abdul Manan, M., & Mansor, A. (2023). The effects of heat treatments on the bioactive compounds, antioxidant activity

and cosmeceutical properties (anti-pigmentation and anti-ageing) of fermented broken rice. *Food Research*, 6(Suppl. 2), 155-162.

Akinwumi, A. O., & Olagoke O. C. (2019). Effects of different natural antioxidants and storage time on nutritional and microbiological qualities of chicken sausage. *International Journal of Science and Research*, 8(9), 1700-1705.

Akoh, C. C. (1998). Fat replacers. *Food Technology*, 52(3), 47-53.

American Public Health Association (APHA) (1984). Compendium of methods for the microbiological examination of foods. 2nd edition. Speck, M. L. (ed.). Washington, DC.

Arshad, M. S., Imran A., Nadeem, M. T., Sohaib, M., Saeed, F., Anjum, F. M., Kwon, J., & Hussain, S. (2017). Enhancing the quality and lipid stability of chicken nuggets using natural antioxidants. *Lipids in Health and Disease*, 16(108), 1-9.

Association of Official Analytical Chemists (AOAC) (2019). Official methods of analysis (18th edition). Washington, DC, USA.

Bertram, H. C., Andersen, H. J., Karlsson, A. H., Horn, P., Hedegaard, J., Nørgaard, L., & Engelsen, S. B. (2003). Prediction of technological quality (cooking loss and Napole Yield) of pork based on fresh meat characteristics. *Meat Science*, 65(2), 707-712.

Bhat, Z. F., Kumar, P., & Kumar, S. (2013). Effect of skin, enrobing and refrigerated storage on the quality characteristics of chicken meat balls. *Journal of Food Science and Technology*, 50, 890-899.

Broncano, J. M., Petrón, M. J., Parra, V., & Timón, M. L. (2009). Effect of different cooking methods on lipid oxidation and formation of free cholesterol oxidation products (COPs) in Latissimus dorsi muscle of Iberian pigs. *Meat science*, 83(3), 431-437.

Cáceres, E., García, M. L., & Selgas, M. D. (2006). Design of a new cooked meat sausage enriched with calcium. *Meat Science*, 73(2), 368-377.

Cholan, P., Rao, V. K., Karthikeyan, B., Moorthy, P. R., & Cytyarasan, S. (2011). Effect of different cooking methods on the physicochemical, organoleptic and microbiological quality of chicken patties. *Indian Journal of Poultry Science*, 46(2), 206-210.

Chonpracha, P., Ardoin, R., Gao, Y., Waimaleongora-Ek, P., Tuuri, G., & Prinyawiwatkul, W. (2020). Effects of intrinsic and extrinsic visual cues on consumer emotion and purchase intent: A case of ready-to-eat salad. *Foods*, 9(4), 396.

- Clausen, I., & Ovesen, L. (2005). Changes in fat content of pork and beef after pan-frying under different conditions. *Journal of Food Composition and Analysis*, 18(2-3), 201-211.
- da Silva, M. F. G., de Sousa, P. H. M., Figueiredo, R. W., Gouveia, S. T. Silva, J., & Lima, S. (2019). Cooking effects on bioactive compounds and sensory acceptability in pumpkin (*Cucurbita moschata* cv. Leite). *Revista Ciência Agronômica*, 50(3), 394-401.
- Egyptian Organization for Standardization and Quality Control (EOSQC) (2005). Egyptian standards for frozen poultry and rabbit. Egyptian Organization for Standardization and quality control. No. 1090.
- El-Anany, A. M., Ali, R. F.M., & El-Anany, A. M. M. (2020). Nutritional and quality characteristics of chicken nuggets incorporated with different levels of frozen white cauliflower. *Italian Journal of Food Science*, 32, 45-59.
- Fathy-Eman, A. R. (2012). Chemical analysis of chicken meat with relation to it's quality. Ph.D. Thesis, Faculty of Veterinary Medicine, Banha University.
- Fernandez-Lopez, J., Jim'enez, S., Sayas-barber'a, E., Sendra, E., & P'erez-Alvarez, J. (2006). Quality characteristics of ostrich (*Struthio camelus*) burgers. *Meat Science*, 73, 295-303.
- Hayes, J. E. (2009). Sensory descriptors for cooked meat products. In: Nollet, L. M. L., & Toldrá, F. (eds.). *Handbook of processed meats and poultry analysis*. CRC Press, Taylor and Francis Group, Pp. 399-421.
- Hoffman, L. C., & Wiklund, E. (2006). Game venison-meat for the modern consumer. *Meat Science* 74(1), 197-208.
- Hwang, K., Choi, Y., Choi, J., Kim, H., Kim, H., Lee, M., Chung, H., & Kim, C. (2011). Effect of Ganghwayakssuk (*Artemisia princeps Pamp.*) on Oxidative stability of deep fried chicken nuggets. *Food Science and Biotechnology*, 20(5), 1381-1388.
- Innawong, B., Mallikarjunan, P., Marcy, J., & Cundiff, J. (2006). Pressure conditions and quality of chicken nuggets fried under gaseous nitrogen atmosphere. *Journal of Food Processing and Preservation*, 30(2), 231-245.
- Jackson, V., Schilling, M. W., Falkenberg, S. M., Schmidt, T. B., Coggins, P. C., & Martin, J. M. (2009). Quality characteristics and storage stability of baked and fried chicken nuggets formulated with wheat and rice flour. *Journal of Food Quality*, 32(6), 760-774.
- Kearsley, M. W., EL-Khatib, L., & Gunu, C. O. K. (1983). Rapid determination of total volatile nitrogen in fish and meat. *Association of Public Analysts*, 21, 123-128.
- Liu, F., Dai, R., Zhu, J., & Li, X. (2010). Optimizing color and lipid stability of beef patties with a mixture design incorporating with tea catechins, carnosine, and α -tocopherol. *Journal of Food Engineering*, 98(2), 170-177.
- Lorenzo, J. M., & Domínguez, R. (2014). Cooking losses, lipid oxidation and formation of volatile compounds in foal meat as affected by cooking procedure. *Flavour and Fragrance Journal*, 29(4), 240-248.
- Lukman, I., Huda, N., & Ismail, N. (2009). Physicochemical and sensory properties of commercial chicken nuggets. *Asian Journal Food and Agro-Industry*, 2(02), 171-180.
- Mazza, G. (2000). *Alimentos funcionales: Aspectos bioquímicos y de procesado*, First Edition.
- Mena-García, M., Paula, V. B., Olloqui, N. D., García, D. F., Combarros-Fuertes, P., Estevinho, L. M., & Fresno-Baro, J. M. (2021). Effect of different cooking methods on the total phenolic content, antioxidant activity and sensory properties of wild *Boletus edulis* mushroom. *International Journal of Gastronomy of Food Science*, 26, 100416.
- Miglio, C., Chiavaro, E., Visconti, A., Fogliano, V., & Pellegrini, N. (2008). Effects of different cooking methods on nutritional and physicochemical characteristics of selected vegetables. *Journal Agricultural and Food Chemistry*, 56(1), 139-147.
- Mir-Bel, J., Oria, R., & Salvador, M. L. (2012). Influence of temperature on heat transfer coefficient during moderate vacuum deep-fat frying. *Journal Food Engineering*, 113(2), 167-176.
- Naveena, B. M., Muthukumar, M., Sen, A. R., Babji, Y., & Murthy T. R. K (2006). Quality characteristics and storage stability of chicken patties formulated with finger millet flour (*Eleusine coracana*). *Journal of Muscle Foods*, 17, 92-104.
- Parvin, R., Zahid, M. A., Seo, J. K., Park, J., Ko, J., & Yang, H. S. (2020). Influence of reheating methods and frozen storage on physicochemical characteristics and warmed-over flavor of nutmeg extract-enriched precooked beef meatballs. *Antioxidants*, 9(8), 670.
- Pathare, P. B., & Roskilly, A. P. (2016). Quality and energy evaluation in meat cooking. *Food Engineering Reviews*, 8, 435-447.
- Pathera, A. K., Riar, C. S., Yadav, S., & Singh, P. K. (2016). Effect of cooking methods on lipid oxidation, microbiological and sensory quality of chicken nuggets under refrigerated storage. *Cogent Food & Agriculture*, 2, 1232472.
- Pietrasik, Z., Dhanda, J. S., Pegg, R. B., & Shand, P. J. (2005). The effects of marination and cooking regimes on the waterbinding properties and tenderness of beef and bison top round roasts. *Journal of food science*, 70(2), S102-S106.
- Reid, T., Munyanyi, M., & Mdluza, T. (2017). Effect of cooking and preservation on nutritional and phytochemical composition of the mushroom *Amanita zambiana*. *Food Science and Nutrition*, 5(3), 538-544.
- Resurreccion, A. V. A. (2004). Sensory aspects of consumer choices for meat and meat products. *Meat Science*, 66(1), 11-20.
- Rinaldi, M., Chiavaro, E., & Massini, R. (2010). Apparent thermal diffusivity estimation for the heat transfer modelling of pork loin under air/steam cooking treatments. *International Journal of Food Science and Technology*, 45(9), 1909-1917.
- Saguy, I. S., & Pintus, E. J. (1995): Oil up take during deep fat frying: Factors and mechanism. *Food Technology*, 49, 142-145.
- Senevirathne, M., Kim, S. H., Siriwardhana, N., Ha, J. H., Lee, K. W., & Jeon, Y. J. (2006). Antioxidant potential of ecklonia cavaon reactive oxygen species scavenging, metal chelating, reducing power and lipid peroxidation inhibition. *Food Science and Technology International*, 12(1), 27-38.
- Sharima-Abdullah, N., Hassan, C. Z., Arifin, N., & Huda-Faujan, N. (2018). Physicochemical properties and consumer preference of imitation chicken nuggets produced from chickpea flour and textured vegetable protein. *International Food Research Journal*, 25(3), 1016-1025.
- Statistical Analysis System Institute (SAS) (2014). *Statistical analysis system*. The SAS Institute, Cary, NC.
- Traore, S., Aubry, L., Gatellier, P., Przybylski, W., Jaworska, D., Kajak-Siemaszko, K., & Santé-Lhoutellier, V. (2012). Effect of heat treatment on protein oxidation in pig meat. *Meat Science*, 91(1), 14-21.
- Turhan, S., Temiz, H., & Sagir, I. (2007). Utilization of wet okara in low-fat beef patties. *Journal of Muscle Foods*, 18(2), 226-235.

- Vittadini, E., Rinaldi, M., Chiavaro, E., Barbanti, D., & Massini, R. (2005). The effect of different convection cooking methods on the instrumental quality and yield of pork *Longissimus dorsi*. *Meat Science*, 69(4), 749-756.
- Yadav, S., Malik, A., Pathera, A., Islam, R. U., & Sharma, D. (2016). Development of dietary fibre enriched chicken sausages by incorporating corn bran, dried apple pomace and dried tomato pomace. *Nutrition and Food Science*, 46(1), 16-29.
- Yavas, E., & Bilgin, B. (2010). Effect of calcium lactate, sodium diacetate and sodium chloride mixture on the microbiological, chemical and sensory properties of chicken nuggets stored in refrigeration and under modified atmospheres. *International Journal of Poultry Science*, 9(1), 66-71.
- Yogesh, K., Ahmad, T., Manpreet, G., Mangesh, K., & Das, P. (2013). Characteristics of chicken nuggets as affected by added fat and variable salt contents. *Journal of Food Science and Technology*, 50, 191-196.