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## FOOD SCIENCE & TECHNOLOGY | RESERACH ARTICLE

# Effect of cooking methods on lipid oxidation, microbiological and sensory quality of chicken nuggets under refrigerated storage

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**Abstract:** This study was conducted to evaluate the effect of oven, steam and microwave cooking methods on lipid oxidation, microbiological and sensory quality of chicken nuggets. Nuggets were prepared and analyzed at a regular interval of 5 days from day of production to spoilage of products under refrigerated storage. Cooking methods significantly affected the lipid oxidation of nuggets under refrigerated storage. Highest lipid oxidation was reported in microwave cooked nuggets, however cooking methods did not affect the microbiological quality of nuggets during storage. Products were safe for consumption up to 15 days at refrigerated storage as the microbial count had not exceeded the permissible limit. Steam cooked nuggets had better sensory scores in comparison to microwave and oven. Overall acceptability scores for all the products were more than 6.0 at the end of storage period, reflecting more than moderate acceptance till the products were microbiologically safe.

**Subjects:** Food Microbiology; Lipids; Meat & Poultry; Sensory Science

**Keywords:** chicken nuggets; cooking methods; refrigerated storage; lipid oxidation

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### PUBLIC INTEREST STATEMENT

Cooking of meat results in several quality changes and it has both positive and negative effects on quality characteristics. Present study investigated the effect of specific cooking technique (dry heat, moist heat and microwave) on lipid oxidation, microbiological and sensory quality of chicken nuggets under refrigerated storage. There is scanty information available on this aspect, as limited number of studies has been conducted to assess the quality of meat products prepared by different cooking techniques. Increased lipid oxidation has influence on product acceptability and a remarkable difference in lipid oxidation was observed in nuggets cooked by oven, steam and microwave cooking. Microbial counts were not influenced by difference in cooking techniques. Steam cooked nuggets showed superior sensory quality. Microwave cooking resulted in inferior products in terms of oxidative stability and overall sensory quality. Hence, the present findings suggest that steam cooking is a better method than oven and microwave cooking.



Ashok K. Pathera

## 1. Introduction

Meat has to be cooked before consumption and cooking of meat results in quality changes such as flavor and taste enhancement, inhibition of microorganism, shelf life increase and improved digestibility (Broncano, Petrón, Parra, & Timón, 2009). Cooking not only contributes to the stability of meat products, but also plays an important role in providing variety of meat products, which can be achieved by modifying cooking procedures. However, it has both positive and negative effects on quality attributes of meat (Özcan & Bozkurt, 2015). Cooking is the most important technology for taste and odour compound formation; however, it is also the main reason for the deterioration of this product giving undesirable odours, rancidity, texture modification, nutritional losses and toxic compound production (Broncano et al., 2009). Lipid oxidation is considered to be the main reason for the negative changes in meat and meat products and is affected by the temperature and duration of the storage (Morrissey, Sheehy, Galvin, Kerry, & Buckley, 1998).

Cooking methods influence the color, texture, flavor, nutritional composition and microbial load of final product. Each cooking method has its own advantages and disadvantages depending upon the product processed (Cholan, Rao, Karthikeyan, Sreenivasamoorthy, & Cytyarasan, 2011). Types of cooking method affect the sensory properties such as flavor, color, texture, palatability and tenderness of meat and meat products (Pietrasik, Dhanda, Pegg, & Shand, 2005). Several studies have been conducted to assess the effect of cooking methods on quality and storage stability of chicken patties (Cholan et al., 2011), Turkey meat balls (Chettri, Kulkarni, Mahapatra, & Kumar, 2011), chicken nuggets (Adedeji, Ngadi, & Raghavan, 2009; Ngadi, Wang, Adedeji, & Raghavan, 2009), chicken meat chat (Singh, Pathak, Verma, Kumar, & Kumar, 2012), beef and Turkey meat (Peiretti, Medana, Visentin, Bello, & Meineri, 2012), Latissimus dorsi muscle of Iberian pigs (Broncano et al., 2009), foal meat (Domínguez, Gómez, Fonseca, & Lorenzo, 2014), silver catfish fillets (Weber, Bochi, Ribeiro, Victório, & Emanuelli, 2008) and restructured beef steaks (Serrano, Librelotto, Cofrades, Sánchez-Muniz, & Jiménez-Colmenero, 2007). In continuance, this study was conducted to determine the influence of different cooking methods on lipid oxidation, sensory and microbiological quality of chicken nuggets.

## 2. Materials and methods

### 2.1. Chicken meat

Broiler birds of 6–7 weeks age reared under similar feeding and managerial conditions were slaughtered and dressed as per the standard procedure in slaughter house of Department of Livestock Products Technology, Lala Lajpat Rai University of Veterinary and Animal Sciences. Carcasses were washed thoroughly and deboned manually after trimming of visible fat and connective tissue. Deboned meat was frozen and stored in deep freezer (–18°C) for further use.

### 2.2. Nuggets preparation

Deboned meat was minced in an electrical mincer (MADO Primus, model MEW 613, Germany) by 4 mm plate. Already optimized three different formulations, aimed for dietary fiber enrichment by incorporation of wheat bran (Table 1), were used to prepare nuggets by oven, steam and microwave cooking methods. Minced meat, common salt, sodium tripolyphosphate, sodium nitrite, chilled water, spice mix, condiment paste, refined wheat flour, egg albumen, fat (groundnut oil) and wheat bran were mixed in a bowl chopper (Stadler Corporation, India) to prepare emulsion. Emulsions were prepared separately as per formulation for oven, steam and microwave cooking. Equal weight of emulsion was stuffed in rectangular moulds of same size and was cooked by oven (in a preheated electrical oven of Ditz Electricals Ltd, India, at 165°C temperature for 35 min), steam (in a closed container at sim gas flame for 30 min) and microwave oven (Samsung, model C103FL, at 2450 MHz and 900 W) for 5 min. The internal temperatures of products were recorded by inserting a probe thermometer into the centre. Preliminary trials for time and temperature combination were conducted to determine the length of cooking time required to reach the designated internal temperature (80°C). Cooked products were cooled to room temperature. Nuggets were prepared by slicing cooked emulsion to 2–3 cm<sup>3</sup> size.

**Table 1. Formulation for dietary fiber enriched chicken nuggets**

Ingredients	F-ON	F-SN	F-MN
Minced meat	100 g	100 g	100 g
Common salt	2.5 g	2.5 g	2.5 g
Sodium nitrite	20 mg	20 mg	20 mg
Sodium tripolyphosphate	400 mg	400 mg	400 mg
Spice mix	3 g	3 g	3 g
Condiments paste	4 g	4 g	4 g
Refined wheat flour	3 g	3 g	3 g
Chilled water	12 g	12 g	12 g
Egg albumen	12.9 g	10.1 g	9 g
Fat	10.2 g	8.5 g	8.6 g
Wheat bran	10.6 g	12.5 g	8.3 g

Notes: F-ON: raw formulation for oven cooked nuggets, F-SN: raw formulation for steam cooked nuggets, F-MN: raw formulation for microwave oven cooked nuggets.

### 2.3. Refrigerated storage

Nuggets were packaged in low density polyethylene bags and stored at refrigeration temperature of  $4 \pm 1^\circ\text{C}$  and samples were drawn at regular interval of 5 days from day of production (0 day), till spoilage of products. Initially lipid oxidation and microbiological quality were analyzed to determine the shelf life of products, and then sensory quality was determined up to the shelf life of nuggets at interval of 5 days during refrigerated storage.

### 2.4. Lipid oxidation

Lipid oxidation in terms of thiobarbituric acid reactive substances (TBARS) value of chicken nuggets was estimated. The extraction method described by Witte, Krause, and Bailey (1970) was used with slight modifications for the determination of TBARS value of nuggets. A 5 g of sample was blended for 3 min with 25 mL of 20% trichloroacetic acid. The contents were filtered through Whatman No. 42 filter paper. Then, 5 mL of trichloroacetic acid extract (filtrate) was mixed with equal amount of 2-thiobarbituric acid (1 mg/mL) reagent. After mixing the contents, tubes were kept in a boiling water bath for 35 min. Blank was run simultaneously to check the experimental error. Absorbance was measured by spectrophotometer (Genesys 10 S UV-vis, Thermoscientific, Virginia, United States) at 532 nm. A standard curve of 1, 1, 3, 3 tetra ethoxy propane (TEP) was made by using 1, 2, 3, 4 and 5 mL of TEP (3  $\mu\text{g/mL}$ ). TBARS was calculated as mg malonaldehyde per kg of sample by using standard curve of TEP.

### 2.5. Microbiological evaluation

Standard plate count (SPC) (log cfu/g), psychrotrophic count (PC) (log cfu/g) and yeast and mould count (log cfu/g) were determined by using method recommended by APHA (1984).

### 2.6. Sensory evaluation

Sensory evaluation was carried out by a semi trained panel from the faculty and research fellows of the department. Panelists were well aware about sensory characteristics and had good experience of sensory analysis of meat products. Sensory attributes viz color and appearance, flavor, texture, tenderness, juiciness and overall acceptability (OAA) were evaluated using 8-point descriptive scale (where 8 indicates extremely desirable and 1 indicates extremely undesirable) (Keeton, 1983).

### 2.7. Statistical analysis

Statistical analysis of the data obtained from 6 replicates was done by ANOVA. Duncan's multiple range test at 5% significance level was applied to find out significant differences in mean (Snedecor & Cochran, 1989) and results were expressed as mean  $\pm$  standard deviation.

### 3. Results and discussion

#### 3.1. Lipid oxidation

Lipid oxidation in terms of TBARS value of chicken nuggets expressed as mg malonadehyde/kg of product is presented in Table 2. Cooking of meat increased TBARS value because high temperature during cooking causes an increase in oxidation process in meat products (Broncano et al., 2009). A significant effect of cooking methods was observed on lipid oxidation of nuggets. Serrano et al. (2007) reported that significant interactions between cooking method and type of meat product were observed through TBARS values. Significantly ( $p < 0.05$ ) higher lipid oxidation was observed in microwave cooked nuggets and least was in steam cooked nuggets and results were also in agreement with Weber et al. (2008) who found highest oxidation in microwave baked silver catfish fillets. Serrano et al. (2007) reported change in TBARS values of restructured beef steaks induced by microwave oven cooking. Naveena, Muthukumar, Muthulakshmi, Anjaneyulu, and Kondaiah (2014) observed similar observations on vacuum packaged emulsion products from chicken. Broncano et al. (2009) suggested that oxidation processes during cooking are more affected by a longer time and lower temperature than by a shorter time and higher temperature but also reported that samples cooked by microwave had high levels of oxidation compounds even though the low temperature and short time used in the process and as a result this suggests some interaction between microwave and meat fat which causes oxidation of polyunsaturated fatty acids. Regardless of raw formulation, the cooking process did not always cause an increase in TBARS values (Serrano et al., 2007). TBARS value in all products increased significantly with the advancement of storage period. However, lipid oxidation for oven cooked nuggets showed significantly ( $p < 0.05$ ) higher TBARS values than steam cooked nuggets and significantly ( $p < 0.05$ ) lower TBARS values than microwave cooked nuggets under the refrigerated storage. Similar increase in TBARS during refrigerated storage period was also reported in chicken emulsion (Kala, Kondaiah, Anjaneyulu, & Thomas, 2007), lamb meat (Popova & Marinova, 2013), pressurized and cooked chicken (Beltran, Pla, Yuste, & Mor-Mur, 2003), chicken seekh kababs (Bhat, Pathak, Ahmad, Bukhari, & Kumar, 2010) and chicken meat balls, patties and nuggets (Biswas, Chatli, Sahoo, & Singh, 2012). According to Al-Kahtani et al. (1996) meat products

**Table 2. Lipid oxidation and microbiological quality of chicken nuggets at refrigerated storage**

Treatments	0 Day	5th Day	10th Day	15th Day	20th Day
<i>TBARS value (mg malonadehyde/kg)</i>					
ON	0.79 ± 0.25 <sup>bE</sup>	1.12 ± 0.24 <sup>bd</sup>	1.59 ± 0.25 <sup>bc</sup>	2.00 ± 0.26 <sup>bb</sup>	2.60 ± 0.28 <sup>ba</sup>
SN	0.44 ± 0.24 <sup>cE</sup>	0.79 ± 0.26 <sup>cd</sup>	1.25 ± 0.23 <sup>cc</sup>	1.63 ± 0.29 <sup>cb</sup>	2.15 ± 0.30 <sup>ca</sup>
MN	1.12 ± 0.25 <sup>aE</sup>	1.57 ± 0.26 <sup>ad</sup>	2.07 ± 0.32 <sup>oc</sup>	2.59 ± 0.28 <sup>ob</sup>	3.23 ± 0.33 <sup>oa</sup>
<i>Standard plate count (log cfu/g)</i>					
ON	2.15 ± 0.40 <sup>E</sup>	3.36 ± 0.31 <sup>D</sup>	4.29 ± 0.35 <sup>C</sup>	5.12 ± 0.31 <sup>B</sup>	6.20 ± 0.41 <sup>A</sup>
SN	2.46 ± 0.42 <sup>E</sup>	3.13 ± 0.32 <sup>D</sup>	4.12 ± 0.33 <sup>C</sup>	5.34 ± 0.40 <sup>B</sup>	6.42 ± 0.43 <sup>A</sup>
MN	2.30 ± 0.39 <sup>E</sup>	3.45 ± 0.45 <sup>D</sup>	4.39 ± 0.38 <sup>C</sup>	5.05 ± 0.26 <sup>B</sup>	6.11 ± 0.35 <sup>A</sup>
<i>Psychrotrophic count (log cfu/g)</i>					
ON	1.10 ± 0.59 <sup>C</sup>	1.53 ± 0.43 <sup>C</sup>	2.20 ± 0.44 <sup>B</sup>	2.39 ± 0.38 <sup>B</sup>	3.26 ± 0.47 <sup>A</sup>
SN	1.30 ± 0.65 <sup>D</sup>	1.65 ± 0.32 <sup>CD</sup>	2.05 ± 0.39 <sup>BC</sup>	2.54 ± 0.32 <sup>AB</sup>	3.02 ± 0.42 <sup>A</sup>
MN	1.01 ± 0.41 <sup>C</sup>	1.25 ± 0.58 <sup>C</sup>	2.13 ± 0.38 <sup>B</sup>	2.47 ± 0.41 <sup>B</sup>	3.10 ± 0.33 <sup>A</sup>
<i>Yeast and mould count (log cfu/g)</i>					
ON	0.68 ± 0.52 <sup>C</sup>	1.15 ± 0.40 <sup>BC</sup>	1.42 ± 0.39 <sup>B</sup>	2.18 ± 0.34 <sup>A</sup>	2.37 ± 0.36 <sup>A</sup>
SN	0.75 ± 0.39 <sup>D</sup>	1.29 ± 0.65 <sup>C</sup>	1.56 ± 0.30 <sup>BC</sup>	2.02 ± 0.38 <sup>B</sup>	2.60 ± 0.42 <sup>A</sup>
MN	0.82 ± 0.52 <sup>C</sup>	1.05 ± 0.43 <sup>C</sup>	1.67 ± 0.35 <sup>B</sup>	1.96 ± 0.52 <sup>AB</sup>	2.43 ± 0.37 <sup>A</sup>

Notes: (n = 6, Mean ± SD).

ON: oven cooked nuggets, SN: steam cooked nuggets, MN: microwave oven cooked nuggets.

Means with different small superscripts within a column and capital superscripts within a row differ significantly ( $p < 0.05$ ).

having less than 3 mg MDA/kg can be considered in a good preservation state with reference to oxidative changes. Henceforth, all nuggets estimated for TBARS were fit for consumption.

### 3.2. Microbiological quality

It was observed from the results that microbiological quality of nuggets was not affected by methods of cooking (Table 2). All the microbial counts were significantly increased during the refrigerated storage period. Similar increase in microbial counts during refrigerated storage period was also reported in chicken emulsion (Kala et al., 2007), chicken meat nuggets (Yavas & Bilgin, 2010), chicken seekh kababs (Bhat et al., 2010), and chicken meat balls, patties and nuggets (Biswas et al., 2012). SPC were above 2 log cfu/g on first day of storage and reached to a level above 6 log cfu/g on 20th day of refrigerated storage. The microbial counts of nuggets were in acceptable limits till 15th day of refrigerated storage but on 20th day all products were not fit for consumption. Shelf life of products were found up to 15 days as the standard plate count (SPC) and psychrotrophic count (PC) had not exceeded the permissible limit of 6log cfu/g of sample for SPC (Jay, 1996) and 4.6 log cfu/g for PC (Cremer & Chipley, 1977). Meat products have been reported to get spoiled at a microbial load of more than 6 log cycles (Frazier & Westhoff, 1978). Similarly, it was observed that SPC counts were within the limits of 6 log cfu/g prescribed for safe cooked meat products (Shapton & Shapton, 1991). The results were in agreement with Cholan et al. (2011) who reported no significant difference in SPC of chicken patties cooked by steaming water bath, microwave oven and hot air oven. Similar results of microbiological quality were also reported by Mehta, Ahlawat, Sharma, Yadav, and Arora (2013) in chicken patties and Yadav, Malik, Pathera, Islam, and Sharma (2016) in chicken sausages.

**Table 3. Sensory quality of chicken nuggets at refrigerated storage**

Treatments	0 Day	5th Day	10th Day	15th Day
<i>Color &amp; appearance</i>				
ON	7.28 ± 0.46 <sup>abA</sup>	7.22 ± 0.43 <sup>abA</sup>	6.83 ± 0.38 <sup>abB</sup>	6.33 ± 0.49 <sup>abC</sup>
SN	7.44 ± 0.51 <sup>aA</sup>	7.33 ± 0.49 <sup>aA</sup>	7.11 ± 0.47 <sup>aA</sup>	6.61 ± 0.50 <sup>ab</sup>
MN	7.11 ± 0.32 <sup>bA</sup>	7.00 ± 0.49 <sup>bA</sup>	6.61 ± 0.50 <sup>bB</sup>	6.22 ± 0.43 <sup>bC</sup>
<i>Flavor</i>				
ON	7.06 ± 0.42 <sup>aA</sup>	7.00 ± 0.34 <sup>aA</sup>	6.67 ± 0.49 <sup>ab</sup>	6.39 ± 0.50 <sup>ab</sup>
SN	7.11 ± 0.47 <sup>aA</sup>	6.94 ± 0.54 <sup>aA</sup>	6.56 ± 0.51 <sup>ab</sup>	6.33 ± 0.49 <sup>ab</sup>
MN	6.72 ± 0.46 <sup>bA</sup>	6.61 ± 0.50 <sup>bA</sup>	6.22 ± 0.43 <sup>bB</sup>	6.00 ± 0.49 <sup>bB</sup>
<i>Texture</i>				
ON	6.78 ± 0.43 <sup>bA</sup>	6.67 ± 0.49 <sup>bAB</sup>	6.39 ± 0.50 <sup>bBC</sup>	6.22 ± 0.43 <sup>bC</sup>
SN	7.33 ± 0.49 <sup>aA</sup>	7.28 ± 0.46 <sup>aA</sup>	6.89 ± 0.58 <sup>ab</sup>	6.53 ± 0.50 <sup>aC</sup>
MN	6.89 ± 0.32 <sup>bA</sup>	6.78 ± 0.55 <sup>bA</sup>	6.44 ± 0.51 <sup>bB</sup>	6.19 ± 0.39 <sup>bB</sup>
<i>Juiciness</i>				
ON	6.89 ± 0.47 <sup>abA</sup>	6.78 ± 0.43 <sup>abA</sup>	6.44 ± 0.51 <sup>abB</sup>	6.17 ± 0.38 <sup>abB</sup>
SN	7.11 ± 0.47 <sup>aA</sup>	7.06 ± 0.42 <sup>aA</sup>	6.72 ± 0.46 <sup>ab</sup>	6.44 ± 0.51 <sup>ab</sup>
MN	6.78 ± 0.43 <sup>bA</sup>	6.67 ± 0.49 <sup>bA</sup>	6.33 ± 0.49 <sup>bB</sup>	6.06 ± 0.42 <sup>bB</sup>
<i>Tenderness</i>				
ON	6.83 ± 0.38 <sup>abA</sup>	6.78 ± 0.43 <sup>abA</sup>	6.44 ± 0.51 <sup>abB</sup>	6.17 ± 0.38 <sup>abB</sup>
SN	7.11 ± 0.47 <sup>aA</sup>	7.06 ± 0.42 <sup>aA</sup>	6.72 ± 0.46 <sup>ab</sup>	6.39 ± 0.50 <sup>aC</sup>
MN	6.78 ± 0.43 <sup>bA</sup>	6.67 ± 0.49 <sup>bA</sup>	6.33 ± 0.49 <sup>bB</sup>	6.06 ± 0.42 <sup>bB</sup>
<i>Overall acceptability</i>				
ON	6.89 ± 0.47 <sup>abA</sup>	6.78 ± 0.55 <sup>abA</sup>	6.39 ± 0.50 <sup>abB</sup>	6.22 ± 0.43 <sup>abB</sup>
SN	7.22 ± 0.55 <sup>aA</sup>	7.11 ± 0.47 <sup>aA</sup>	6.67 ± 0.49 <sup>ab</sup>	6.44 ± 0.51 <sup>ab</sup>
MN	6.75 ± 0.49 <sup>bA</sup>	6.61 ± 0.50 <sup>bA</sup>	6.28 ± 0.46 <sup>bB</sup>	6.11 ± 0.47 <sup>bB</sup>

Notes: (n = 18, Mean ± SD).

ON: oven cooked nuggets, SN: steam cooked nuggets, MN: microwave oven cooked nuggets.

Means with different small superscripts within a column and capital superscripts within a row differ significantly (p < 0.05).

### 3.3. Sensory quality

Sensory evaluation of chicken nuggets indicated that color & appearance, flavor, texture, juiciness, tenderness and overall acceptability were significantly affected by cooking methods (Table 3). Steam cooked nuggets showed significantly higher values for all sensory parameters than oven and microwave cooked nuggets throughout the refrigerated storage. Color & appearance, juiciness, tenderness and OAA scores of oven cooked nuggets were not significantly different than steam and microwave cooked nuggets. Flavor scores of oven cooked nuggets showed significant difference than microwave cooked nuggets. During refrigerated storage, no significant difference was noticed in particular sensory parameters of products up to 5th day of storage but scores decreased significantly on 10th day of storage. Similar decrease in sensory quality during refrigerated storage was also reported in chicken patties (Kala et al., 2007), chicken nuggets (Yavas & Bilgin, 2010; Yogesh, Ahmad, Manpreet, Mangesh, & Das, 2013), chicken seekh kababs (Bhat et al., 2010) and chicken meat balls, patties and nuggets (Biswas et al., 2012). Results for OAA on 15th day showed values between 6.1 to 6.4 and these values reflected the good acceptance of products up to 15th day of refrigerated storage. Chettri et al. (2011) studied the effect of cooking methods on turkey meat balls and reported significantly higher sensory scores in all parameters of oven cooked meat ball than that of microwave cooked meat ball. Yadav et al. (2016) reported similar decrease in sensory scores with increase in storage period of dietary fiber enriched chicken sausages and concluded that lipid oxidation and loss of moisture from products during storage leads to decrease in sensory scores of sausages. Singh et al. (2012) reported significantly higher sensory scores of dry heat cooked meat chat than microwave cooked meat chat.

### 4. Conclusion

It is concluded that steam cooked nuggets resulted in better quality than oven and microwave cooked nuggets. Steam cooking resulted in less lipid oxidation of chicken nuggets in comparison to oven and microwave cooking. This resulted in less deteriorative changes and better sensory quality of steam cooked nuggets. However, microbiological quality was not affected by the type of cooking methods and nuggets showed a shelf life of 15 days at refrigerated storage. Sensory quality parameters of all three nuggets were also acceptable up to the recommended shelf life.

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#### Competing Interests

The authors declare no competing interest.

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