Aquatic Food Studies 3(2), AFS185
https://doi.org/10.4194/AFS185

RESEARCH PAPER

Effect of Sodium Chloride Concentration on Cooking Time Calculation and Sensory Evaluation of Fish Sausage

Mohamed Abd Elgadir[1], Abdalbasit Adam Mariod[2,3,*]

[1]Department of Food Science & Human Nutrition, College of Agriculture and Veterinary Medicine, Qassim University, Buraydah 51452, Saudi Arabia
[2]Department of Biology, College of Science and Arts, Alkamil Branch, University of Jeddah, Alkamil 21931, Saudi Arabia
[3]Indigenous Knowledge and Heritage Centre, Ghibaish College of Science and Technology, Ghibaish P.O. Box 100, Sudan

How to Cite

Elgadir, M., A., Mariod, A.A. (2024). Effect of Sodium Chloride Concentration on Cooking Time Calculation and Sensory Evaluation of Fish Sausage. *Aquatic Food Studies*, 3*(2), AFS185*. https://doi.org/10.4194/AFS185

Article History
Received 21 September 2023
Accepted 28 December 2023
First Online 28 December 2023

Corresponding Author
E-mail: basitmariod58@gmail.com

Keywords
Fish sausage
Cooking time
Deep fat frying
Sensory evaluation

Abstract

This research was conducted to evaluate the effect of the addition of sodium chloride (NaCl) at different concentrations (0–3.0%) on the theoretical and real cooking time and sensory evaluation of the fish sausage. The fish sausage was prepared using 2:1.2:1 minced fish, sago starch, and water with added NaCl at a concentration of 1.5% to the formulation, and the sausage was cooked for 180 seconds (3 min) at 180°C to accomplish both the correct cooking time and sensory evaluation properties. Theoretical and real cooking time methods were calculated using a pre-calibrated thermocouple to reach the target core temperature of 75ºC at the centre of the sausage. The optimum NaCl concentration and cooking time were identified from the cooking methods and sensory evaluation. The results revealed that increasing the addition of NaCl to the sausage formulations significantly increased the core temperature of the sausage during cooking. There was a reverse relationship between the added percentage of sodium chloride and the calculated cooking time; as the addition of sodium chloride increased, a shorter cooking time was obtained until we reached the target core temperature of 75ºC. The predicted cooking time was 195.171 seconds, and the real cooking time was 180 seconds.

Introduction

Fish and fish product are highly nutritious food in the human diet. They considered as important sources of protein, minerals, polyunsaturated fatty acids (PUFA) such as Docosa Hexaenoic Acids and Eicosa Pentaenoic acid (Sanchari & Kuntal, 2020). Fish sausage is especial type of sausages and consider as one of several fishery products such as fish balls, fish cakes and fish crackers, which commonly originated in Asian countries like China, Thailand, Taiwan, Indonesia, and Malaysia (Yeap & Melvin, 2011). It is consumed as snack food after frying. Minced fish and starch are the two main essential ingredients in making this product (Cheow et al., 1999; Kyaw, 2004; Murad et al., 2017; Cortez et al., 2020) . The ingredients used in formulation of the fish sausage in Malaysia vary from state to another to maximize profit, which could affect its thermal properties (Kaewmanee et al., 2015) and cooking time. Deep - fat frying is one of the good cooking methods techniques for cooking of fried products such as fish sausage and it is considered as an important food processing operation (Achir et al. 2008; Sobowale et al., 2019) During this process it is very important to adjust the time and temperature of cooking since most of the food products have an optimum cooking time and temperature. Many authors have reported that if the frying time exceeds the optimum time, the finished product will be over cooked

Published by Central Fisheries Research Institute (SUMAE) Trabzon, Türkiye.

and tended to have higher oil content (Kayader et al., 1999; Esturk et al., 2000; Pedreschi et al., 2005; Moyano et al., 2006; Jirawan et al., 2009; Bahram et al., 2014; Xu et al., 2020; Wang et al., 2021) contrast, if the product is fried for insufficient time, it will not release the retained moisture and result in a soggy texture (Topete-Betancourt et al., 2019). The optimum frying temperature and time are important to prevent a semi-raw and oily product at too low frying temperatures and a burnt product at too high frying temperatures (Rossell, 2001). Correct knowledge of thermal properties is essential for efficient and economical design and control of all food processing operations involving heat transfer such as heating, cooling and frying (Wu et al., 2013; Ziaiifar et al., 2021). The design and selection of cooking method help in reducing some health risks associated with fried food consumption, namely co-consumption of oil picked up by the food during frying. Success in design and selection of cooking method also help in reducing the formation of acrylamide and carcinogen during frying (Saguy et al., 2003; Palazo et al., 2010; Ye et al., 2011; Omini et al., 2019; Knight et al., 2021). It is well documented that food should be cooked thoroughly to kill food poisoning bacteria. To reach this target, the core temperature should reach 75°C instantaneously or equivalent (FAO, 2017). In this study the effects of added sodium chloride with different concentrations on cooking time – temperature and sensory evaluation of fish sausage. This study can help in designing and setting the operation units particularly when such systems are cooked.

Materials and Methods

Preparation of the Fish Sausage

Red telapia fish (*Oreochromis spp*.) was washed, scaled, degutted, deheaded, and mechanically deboned through a 4 mm plate. The control sausage was prepared according to my previously optimized contents published in ARPN Journal of Engineering and Applied Sciences (Abd Elgadir, 2022) with minced fish: sago starch (*Metroxylon sagu*): ice water in ratios of 2:1.2: 1, respectively. 0.5% of black pepper and 0.5% of garlic were added to the formulation before stuffing. The control sausage was remained without adding sodium chloride. All ingredients were placed into a silent bowl cutter (Khin Shang Hoo Iron Works, Guu district, Kaohsiung, Taiwan) and mixed with medium speed for 5 min. The dough-like of the formulation of the sausage was then stuffed into cellulose casings using a sausage stuffer (F- Dick, Esslingen, Germany). The stuffed sausage samples were then used for further studies.

Calculation of Thermal Properties and Cooking Time of Fish Sausage

In order to determine the cooking time (deep-fat frying time) of the samples as affected by either sodium chloride or sucrose concentrations, the thermal conductivity (k)., the specific heat (cp), the density and the thermal diffusivity (α) were first calculated using the following equations:

Calculation of Thermal Conductivity of Fish Sausage

The thermal conductivity values of the samples were measured using the general following equation (equation 1) which was developed by Sweat (Sweat, 1985):

$$k = 0.48X_w + 0.155X_p + 0.25X_c + 0.16X_f + 0.135X_a \quad (1)$$

Where;

k: Thermal conductivity (W/m^2.^{o}C)
X_w, X_p, X_c, X_f and X_a: The sample moisture, protein, carbohydrate, fat and ash contents

Calculation of specific heat capacity of fish sausage

The specific heat capacity values of the samples were determined using the equation (equation 2) given below (Ansari et al., 2003):

$$Cp = Cc\,Xc + Cp\,Xp + Cf\,Xf + Ca\,Xa + Cw\,Xw \quad (2)$$

Where;

C_p: Specific heat capacity (J.kg^{-1} ^{o}C^{-1})
Cc Xc: Specific heat capacity of carbohydrate x sample carbohydrate content.
Cp Xp: Specific heat of protein x sample protein content.
Cf Xf: Specific heat of fat x sample fat content.
Ca Xa: Specific heat of ash x sample ash content.
Cw Xw: Specific heat of water x sample moisture content.

Calculation of Density of Fish Sausage

The density of the samples was calculated using the equation (equation 3) as given below (Dincer et al., 1996):

$$\rho = \frac{1}{\frac{x_c}{\rho_c} + \frac{x_p}{\rho_p} + \frac{x_w}{\rho_w} + \frac{x_a}{\rho_a} + \frac{x_F}{\rho_F}} \quad (3)$$

Where;

ρ: Sample density (kg/m^3)
X_c Sample carbohydrate content
X_p Sample protein content
X_w Sample moisture content
X_a Sample ash content
X_f Sample fat contents

Calculation of Thermal Diffusivity of Fish Sausage

The thermal diffusivity of the samples was calculated according to the following equation (equation 4) (Betta et al., 2009):

$$\alpha: k/\rho x\ cp \qquad (4)$$

Where;

α: Thermal diffusivity (m^2/s)
k: Thermal conductivity of the sample ($W/m^2.^oC$)
ρ: The density of the sample (kg/m^3)
cp: Specific heat capacity of the sample ($J\ kg^{-1}\ ^oC^{-1}$)

Calculation of the Predicted Cooking Time of Fish Sausage

The cooking time calculation was determined according to the developed Ansari's Equation (equation 5) (Ansari, 1986).

$$Fo = \left[a + b \cdot \ln\left(\frac{1}{X+0.2}\right) - \ln U\right] / \left[c / \left(1 + d / Bi^e\right)\right] \qquad (5)$$

Where;

Fo: Fourier number = $\alpha t/R^2$
a, b, c, d, e: Constants
Bi: Biot number = hR/k
X: Non- dimentional space co-ordinate
U: Non- dimentional temperature = $T\text{-}T_{oil}/Ti\text{-}T_{oil}$
R: Radius for cylinder shape

Ansari's equation was used to calculate the cooking time of the fish protein - sago starch model because it is suitable and valid to investigate the thermal properties infinite cylinder and sphere (Ansari (1986) [32]. It is capable of making a thorough heat transfer analysis during heating and cooling of solid and liquid bodies. This equation yielded highly reliable results for both temperature calculations and property determination and correlated with the time-temperature records and some of the concerned thermophysical properties of products (Ansari, 1987).

Determination of the Real Cooking Time

The prepared fish sausage with different NaCL concentration which had approximate diameter of 2.6 cm were cut into 10 cm length each and approximately 2.6 cm, moisture content of 78.6 and initial core temperature of 26°C. A pre-calibrated thermocouple model (Elba GTD - 85, Copenhagen, Denmark) was inserted through a centre of the samples individually to measure their core temperature during frying. The samples were wrapped tightly with metal wires to stabilize the thermocouple during the measurement of the temperature of the center point and to control the puffiness. Kawas and Moreira (Kawas et al., 2000) observed up to 100% increase in puffiness around the center of the chip (considering gas bubble expansion) and about a 7% increase in the thickness of the deep-fat fried chip (disregarding the gas bubble expansion). The samples were individually deep - fried in sunflower oil using deep fat fryer model (model DF 30 A 1 T, Japan) adjusted to 180°C for 5 min. The core temperature values were recorded every 10 s.

The initial and surface temperature of the frying oil during frying was recorded using non-contact thermometer model (RAYMAX4+ SN. 001, Germany). After frying, the moisture of the sample was measured using oven drying method. The sample was considered as a finite cylinder with a radius D and a length L. the diameter of the sample (D) was 2.6 cm, and the length (L) was 10 cm (1).

Sensory Evaluation Studies

Sensory evaluation was performed by 30 panelists who regularly consumed fish products. The fried samples measuring 2.5 cm long from each formulation were coded with random 3-digit codes and immediately presented to the panelists in random order under white, fluorescent lights. The panelists were asked to evaluate the sausages for taste, flavor, color, texture, and overall acceptability attributes using a 9-point hedonic scale (neither dislike extremely (1), neither like nor dislike (5) and like extremely (9). Room temperature water was also provided to rinse off mouth between samples evaluation.

Statistical Analysis

The analysis of variance (ANOVA) was performed using the Minitab version 17 statistical package (Minitab Inc., PA, USA). Duncan's test at 95% of confidence level was performed to determine the differences between means.

Results and Discussion

Cooking Temperature and Cooking Time Studies

Table 1 shows the thermophysical properties and cooking time of the different formulations of the fish sausage calculated using Ansari's equation. Equation (1), (2), (3) and (4) were used to calculate the thermal conductivity (k), specific heat capacity (cp), density (ρ) and thermal diffusivity (α) values of the fish sausage, respectively. From the calculation, it was observed that the k value of the sausage increased from 0.419 to 0.585 W/m2°C which indicated that the NaCl caused an increase in k value dramatically. The cp value of the control sausage increased from 3.01 to 3.74 J/kg °C. These results agreed with earlier finding of Heldman and Singh (Heldman et al., 1981) who reported that the specific heat values are always smaller than 4.0 J/kg C. For instance, they found that the specific heat of beef is

Table 1. Thermophysical properties and cooking time calculation as affected by sodium chloride concentration calculated using Ansari's

NaCl%	*k*	*cp*	Density	α	U	ln (U)	aa	*Bi*	*Bi* ^e	RR	FO	t
0	0.563109	3.731233	1046.66	1.4419E-07	0.666667	-0.40547	0.849962	16.39115	18.33132	5.101217	0.166619	195.2893
0.5	0.563664	3.729276	1047.943	1.44231E-07	0.666667	-0.40547	0.849962	16.37501	18.31255	5.100601	0.16664	195.2572
1	0.563607	3.725269	1048.525	1.44291E-07	0.666667	-0.40547	0.849962	16.37666	18.31447	5.100664	0.166638	195.173
1.5	0.564577	3.723418	1050.619	1.44323E-07	0.666667	-0.40547	0.849962	16.34853	18.28176	5.099587	0.166673	195.171
2	0.565148	3.722711	1051.847	1.44328E-07	0.666667	-0.40547	0.849962	16.33199	18.26252	5.098952	0.166693	195.1888
2.5	0.564629	3.725755	1050.533	1.44258E-07	0.666667	-0.40547	0.849962	16.34702	18.27999	5.099529	0.166675	195.2617
3	0.564711	3.726333	1050.632	1.44243E-07	0.666667	-0.40547	0.849962	16.34466	18.27725	5.099438	0.166678	195.2856

3.52 J/kg oC. Sopade and LeGrys (Sopade et al., 1991) and Sopade et al. (Sopade et al., 2004) reported similar observation. They observed that in starchy food the cp value increased from 1.7 to 4.0 J/kg oC during heating. It was observed that there was significant increase in the density with increasing the sucrose and sodium chloride in the model. The calculated density of the control was 1046.7 kg/m3 and increased to maximum values of 1050.6 kg/m3 when 3.0% of sodium chloride is added. This result disagreed with the earlier finding of Moreira and Barrufet (Moreira and Barrufet, 1996) who observed that after deep - deep fat frying at 190°C for 60sec in starchy food system, the bulk density decreases from 880 kg/m3 to 595 kg/m3 after frying In this study the increase in water evaporation during deep-fat frying resulted in an increase in the density due to the increase in the concentration of solid materials in the system as was reported by (Kawas and Moreira, 2000). The calculated values of thermal diffusivities of the sausage varied from 1.19 x 10−7 to 1.51 x 10−7 m2 s−1 during deep-fat frying. The temperature histories of the centre points of the fish sausage during deep-fat frying. There was significant ($p<0.05$) increase in the core temperature of the sausage formulations as compared with their initial temperatures (Figure 1). This result might be due to the swelling and the gelatinization of the starch granules in a food system (Pereira et al., 2020). Earlier, Kyaw et al reported that during the heating of protein-starch system in the fish sausage (keropok lekor) formulation the gelatinization temperature of the starch shifted significantly to a higher value when mixed with fish meat paste. Increasing the addition of sodium chloride caused significant increases in the core temperature of the cooked sausages (figure 1). A gradual increase of core temperature of the sausages were observed in all the formulations as the cooking time increased. These gradual increases in the core temperature might be due to due to large latent heat of vaporization (Yamsaengsung & Moreira, 2002). A reverse relationship between the cooking time and the addition of sodium chloride is observed. As the addition of sodium chloride increased the shorter time of cooking core temperature is obtained to reach the target core temperature.

Sensory Evaluation Studies

The scores of different fish sausage formulations are shown in Table 2. The added sodium chloride resulted in sensory changes of the fish sausage as compared to the control one. It was observed that the control sausage and the sausage formulated with 3.0% of NaCl received the lowest evaluation for both taste and overall acceptability, which may be due to the absence of the NaCl in the control formulation or over salty taste in the sausage formulated with NaCl in the concentration of 3.0%, respectively. All the fish sausages had high evacuation for both flavor and colour attribute with no significant differences ($p > 0.05$) which meant that the addition of NaCl with different concentration had no effect on the flavor and colour attributes of the fish sausage samples. There are no significant differences ($p > 0.05$) in texture attribute of the sausage samples except for the sausage formulated with the addition of NaCl in the concentration of 3.0%. There was a gradual decrease in the texture attributes values, which could be due the effect of sodium chloride on the ionic strength and functional properties of the proteins in the fish meat (Kubota et al., 2006; Horita et al., 2014; Nannan et al., 2017). The sausages received overall acceptability values between 5.0 to 8.8. the lowest value of the overall acceptability was obtained in the sausage treated with NaCl in the concentration of 3.0% followed with the control sausage which may be due to either high concentration or the absence of NaCl. The sausage formulated with NaCl in the concentration of 1.5% received the highest overall acceptability attribute by the panelists (8.8±0.1) as well as the taste (8.7±0.1) and this preferability correlated with the cooking centre temperature (75°C) and cooking time (180s). The results of the sensory evaluation showed that the panelists preferred the system formulated with 60% minced fish, 40% sago starch, 25% water, 0.5% black pepper, 0.5 garlic, 0.5% cinnamon and 1.5% sodium chloride. The calculated cooking time in the range of 195.1 to 195.3 s depends on the concentration of NaCl while the real cooking time for the fish sausage formulated with sodium chloride in the concentration of 1.5% received the highest acceptability by the panellist was 180 s. There was only 15.1 - 15.5 s increase in the cooking time between the calculated and real time, which approved the adequacy of using Ansari equation and the real time methods in this research.

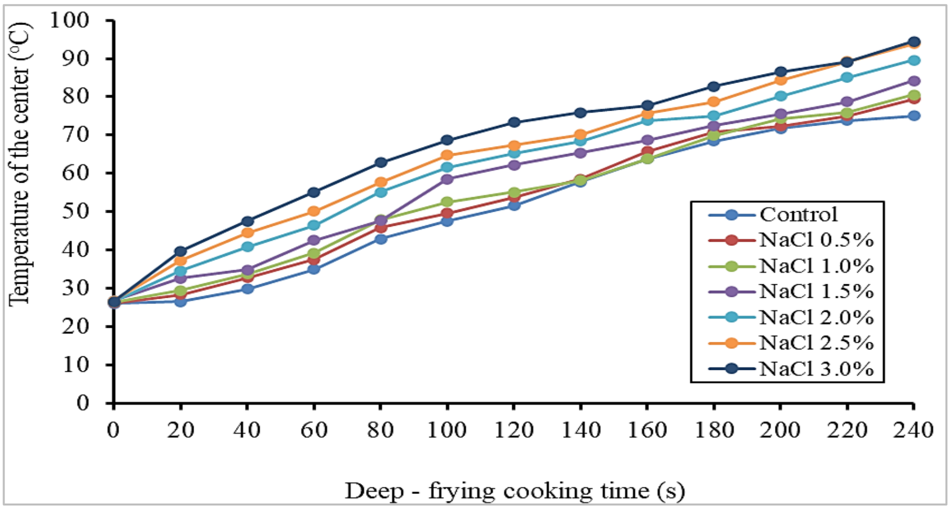

Figure 1. Cooking temperature of the centre of different fish sausage samples formulated with different concentarions of NaCl during deep-fat frying

Table 2. Sensory evaluation of the fish sausage formulated with different concentration of NaCl

Sausage sample	Taste	Flavour	Colour	Texture	Over all acceptability
Control	$4.5±0.3^a$	$7.5±0.2^a$	$7.2±0.2^a$	$6.6±0.5^a$	$5.1±0.1^a$
0.5% NaCl	$5.5±0.4^b$	$7.6±0.1^a$	$7.0±0.5^b$	$6.2±0.2^a$	$6.1±0.3^b$
1.0% NaCl	$5.6±0.2^b$	$7.7±0.5^a$	$7.1±0.1^b$	$6.1±0.1^a$	$7.1±0.4^c$
1.5% NaCl	$8.7±0.1^c$	$7.4±0.2^a$	$7.2±0.2^b$	$6.1±0.2^a$	$8.8±0.1^d$
2.0% NaCl	$5.8±0.2^b$	$7.6±0.1^a$	$6.9±0.1^a$	$6.2±0.4^a$	$6.4±0.2^b$
2.5% NaCl	$5.2±0.3^b$	$7.8±0.3^a$	$6.9±0.6^c$	$6.1±0.2^a$	$6.0±0.3^b$
3.0% NaCl	$4.1±0.1^a$	$7.5±0.2^a$	$7.3±0.3^c$	$5.2±0.5^b$	$5.0±0.3^a$

Readings were means of triplicate measurements
Means with the same superscript letter within the row are not significantly different at p≤0.5

Conclusions

Based on the result of this research, the addition of sodium chloride shifted the core target point temperatures of the sausages to a higher value and shorten the cooking time needed. The sensory evaluation studies revealed that the fish sausage formulated minced fish, sago starch, ice water in the ratios of 2:1.2: 1, respectively with added NaCl at a concentration of 1.5%. 0.5% of black pepper and 0.5 of garlic could be added as seasoning to enhance the sausage sensory attributes and overall acceptability. This fish sausage should be cooked using deep fat frying method at 180°C for 180 s (3min) to reach the target core temperature of 75°C which is highly recommended for well-done cooking and heath purposes.

Ethical Statement

This material is the authors' own original work, which has not been previously published elsewhere. The paper is not currently being considered for publication elsewhere. All authors have been personally and actively involved in substantial work leading to the paper and will take public responsibility for its content. The paper reflects the authors' own research and analysis in a truthful and complete manner.

Funding Information

This research was funded by the deanship of Scientific Research, Qassim University, KSA.

Author Contribution

Mohamed Abd Elagdir and Abdalbasit Adam Mariod, conceptualization (equal); formal analysis (equal); funding acquisition (equal); investigation (equal); project administration (equal); resources (equal); methodology (equal); supervision (equal); validation (equal); visualization (equal); writing – original draft (equal); Writing – review and editing (equal).The authors declare that the present study was conducted in an ethical, professional and responsible manner

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

Acknowledgements

The researchers would like to thank the deanship of Scientific Research, Qassim University for funding the publication of this project.

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