

Physical, Chemical, and Sensory Characteristics of Chicken Sausages Using Corn Oil Instead of Pork Back Fat

Blanca Priscila Maldonado Pacheco^{1,2,*}, Julio Cesar Vinueza Galarraga³, Mar á Jos é Andrade Cuvi⁴,
Montserrat Mor Mur¹

¹Department of Animal and Food Science, Universitat Autònoma de Barcelona (UAB), Spain

²Faculty of Nursing, Research Center for Health in Latin America (CISEAL), Pontifical Catholic University of Ecuador, Ecuador

³Faculty of Exact and Natural Sciences, Pontifical Catholic University of Ecuador, Ecuador

⁴School of Science and Engineering, San Francisco University of Quito, Ecuador

Received May 2, 2024; Revised July 18, 2024; Accepted August 23, 2024

Cite This Paper in the Following Citation Styles

(a): [1] Blanca Priscila Maldonado Pacheco, Julio Cesar Vinueza Galarraga, Mar á Jos é Andrade Cuvi, Montserrat Mor Mur, "Physical, Chemical, and Sensory Characteristics of Chicken Sausages Using Corn Oil Instead of Pork Back Fat," *Food Science and Technology*, Vol. 12, No. 3, pp. 190 - 198, 2024. DOI: 10.13189/fst.2024.120304.

(b): Blanca Priscila Maldonado Pacheco, Julio Cesar Vinueza Galarraga, Mar á Jos é Andrade Cuvi, Montserrat Mor Mur (2024). *Physical, Chemical, and Sensory Characteristics of Chicken Sausages Using Corn Oil Instead of Pork Back Fat*. *Food Science and Technology*, 12(3), 190 - 198. DOI: 10.13189/fst.2024.120304.

Copyright©2024 by authors, all rights reserved. Authors agree that this article remains permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

Abstract Meat and meat products contain important nutrients, such as proteins, essential fatty acids, vitamins, and trace elements that are important for our diet; however, these products also contain elements that can promote the development of multiple diseases, which compels the food industry to create healthier food alternatives. According to the Health and Nutrition Survey (2018), the Ecuadorian diet includes 24% of saturated fatty acids (SFA) and sausages are among the most highly consumed food items. The objective of this research was to develop a sausage with a lower SFA contribution by replacing pork back fat with corn oil without affecting its physicochemical characteristics and sensory acceptability. Two formulations were prepared: pork fat (FT) and corn oil (CO). As the sausage was made, the division in order of vegetable oil addition and cooking start temperature was strictly controlled. The technological properties, proximal composition, fatty acid profile, microbiological quality, and sensory acceptability were analyzed. The results showed that the water loss of FT is higher than that of CO by 1.23%. The two formulations presented an average in total animal proteins of 13.4%, meaning the protein is classified as Type I according to NTE 1338. As for the fatty acid profile, CO contains 20.5% less SFA than FT and has a significantly higher amount of PUFA (by 42.2%). The

overall average acceptance was 4.4% with no statistically significant difference between samples. At 30 days of refrigerated storage, an *E. coli* population < 10UFC/g and absence of *Salmonella* were found. The results show that it is possible to replace 100% of back fat with vegetable oil.

Keywords Saturated Fatty Acids (SFA), Monounsaturated Fatty Acids (MUFA), Polyunsaturated Fatty Acids (PUFA)

1. Introduction

The World Health Organization (WHO) reports that 15 million people die each year from chronic noncommunicable diseases [1]. This problem in the current context generates a higher probability of death; recent studies show that people who are overweight or obese are 7 times more likely to enter an ICU (Intensive Care Unit) due to contracting diseases such as COVID-19 than people with a normal weight [2].

In a report issued by the Food and Agriculture Organization of the United Nations (FAO) on the food security outlook in Latin America and the Caribbean, it was

established that in 2016 the global incidence of overweight people was 39.1% and of obese people was 13.2% in adults over the age of 18 [3] whereas in Latin America, the prevalence of obesity and carrying extra weight is 59.5% [4]. These figures are alarming, especially since they increased between 2020 and 2022 due to lockdowns.

According to the Pan American Health Organization (PAHO), non-communicable diseases (NCDs) kill 41 million people a year. Of these, 71% are caused by cardiovascular diseases associated with tobacco use, physical inactivity, harmful use of alcohol, and unhealthy diets loaded with refined sugars and saturated fats [5] [6].

The consumption of SFA has been shown to be detrimental to health. Metabolic studies have shown that consumption of polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids (MUFA) decreased cholesterol levels, while SFA increased it [7]. Saturated fats have also been shown to have a more stimulatory effect on weight gain and hepatic lipid accumulation than unsaturated fats and may cause changes even at the gut microbiota level [8]. In addition, a high intake of foods rich in saturated and trans fats present in processed foods is associated with neurodegenerative diseases, early cognitive impairment, and Alzheimer's disease. Patients with obesity have a higher amount of adipose tissue, which generates proinflammatory cytokines, thus increasing oxidative stress that increases the risk of Alzheimer's disease by 59% [9] [10].

In Ecuador, according to the latest National Health and Nutrition Survey (ENSANUT) in 2018, 64.68% of the Ecuadorian population aged 19–59 years are overweight or obese. The analysis of the population's dietary habits and frequency of food consumption identified that 20.3% of SFA come from meat. Of this percentage, 12% are derived from processed meat, within which the most highly consumed type is sausages [11]. In 2015, a study was conducted on the fatty acid profile of the most consumed foods in the Metropolitan District of Quito (capital of Ecuador), in which five recognized commercial brands of sausages were analyzed and it was established that on average they contain 36% of SFA [12].

National regulations on meat products have changed over the years. In 1996, in addition to protein content, the addition of pork back fat in meat formulations was limited to a maximum of 25%. The current standard does not place a limit on the percentage of fat in products [13]. The current Ecuadorian standard INEN 1338:2012 establishes that sausages belong to the group of cooked meat products. During processing, they reach an internal temperature of 70 °C and are classified according to total protein (TP) content, broken down into animal (AP) and vegetable (VP), with Type I (TP=min. 12% and max. 2% VP), Type II (PT=min. 10% and max. 4% VP), and Type III (PT= min. 8% VP) [14].

Given this background, the objective of this study was to create a meat sausage with a lower SFA content and a

greater amount of PUFA and MUFA without affecting its sensory, technological, and microbiological characteristics as a healthier product than conventional products by replacing back fat (that has a high SFA content) with corn oil, which has a lower SFA content and a contribution of MUFA and PUFA. It is important to note that despite its high PUFA content, this oil is very stable because it has low SFA and high levels of natural antioxidants [15].

2. Materials and Methods

To establish the different formulations, the methodology was divided into two segments. The first analyzed the technological properties that could be affected by modifying the standard formulation of a conventional sausage, and the second focused on establishing the safety and nutritional contribution of the product.

2.1. Formulation of Sausages

Two types of chicken sausage were made: a conventional formulation using 20% pork back fat (FT) and another using corn oil (CO) instead of pork back fat. The complementary components were not changed.

The chicken breast and fat were ground separately using 5mm and 9mm discs, respectively. All other ingredients were added in equal amounts to the two formulations: 20% crushed ice, 2.1% salt (sodium chloride), 0.2% nitrile salt (6% nitrite curing salt), 0.3% phosphates (sodium tripolyphosphate 4511), 0.3% preservative (sodium acetate, lactic acid, sodium lactate, and acetic acid), and 0.3% Tecnas brand chicken flavoring. The mass was mixed in an emulsifier (4-liter cutter/mixer), with a strict order of adding ingredients to avoid breaking the emulsion. First, the meat and curing salts were added, then the phosphates, preservatives, and 50% of the ice in order to generate the protein matrix, then the remaining ice was incorporated, and the fat and oil were added little by little. The entire process took 20 minutes. The resulting mixture was hermetically stuffed into 20 mm-diameter artificial casings (visflex) and then divided into portions that were approximately 12 cm long per unit. The sausage units were packed in polyethylene bags, labeled, and stored at 4 °C.

During the formulation of the sausages, fractionation was strictly controlled in order of vegetable oil addition (1, 2, and 3 times) and cooking start temperature (30 °C, 45 °C, and 60 °C).

2.2. Technological Properties

2.2.1. Water Holding Capacity (WRC)

The following method [16] was used. Sausages (n=5) were cooked in boiling water. When the center reached 70 °C, they were removed from the cooker and cooled to room temperature. The WRC was determined as the weight loss due to cooking as per Equation (1).

$$WRC = \frac{(Raw\ Breast - Cooked\ Breast)}{Raw\ Breast} \times 100 \quad (1)$$

2.2.2. Weight Loss during Storage (WL)

Losses due to syneresis were evaluated for 20 days. Sausages of 8–10 cm were stored at 4 °C and weighed (n=5) every 4 days after sausage production. WL was expressed as a percentage as per Equation (2).

$$WL = \frac{(Weight\ i - Weight\ f\ (t))}{(Weight\ i)} \times 100 \quad (2)$$

2.3. Proximal Analysis and Physicochemical

This analysis was performed according to official methods described by the AOAC to determine moisture (925.10) [17], ash (923.02) [18] protein (2001.11) [19], and fat (2003.06) [20]. The analyses were performed in duplicate.

The methodology used for the physicochemical analysis of fine paste sausages included the measurement of pH, moisture, acidity, and peroxide value. The samples were stored at 5 °C and analyzed on days 0, 15, and 30. The pH was determined using the method described in NTE INEN ISO 2917:2013 (electrometry), moisture was assessed by the AOAC 925.10 method (gravimetry, air oven), and acidity was measured according to the AOAC 947.05 method (volumetry). The peroxide value was quantified according to the NTE INEN ISO 3960:2013 standard (volumetry), with the results expressed in milliequivalents of oxygen per kilogram of fat (MeqO₂/kg).

2.4. Fatty Acid Profile

The fatty acid content was determined according to the AOAC 996.06 CG method using an Agilent Technologies chromatograph model 6890N equipped with a flame ionization detector (FID). The column used was TRACE TR-Wax of polyethylene glycol (polar phase) of 60 m in length, an internal diameter of 0.25 mm, and a film thickness of 0.25 µm. Total SFA, PUFA, and MUFA were quantified; the results were expressed as a percentage for each fatty acid. The PUFA/SFA ratio and the n-6/n-3 (omega-6/omega-3) ratio were calculated.

2.5. Microbiological Analysis

At 0, 15, and 30 days of refrigerated storage, 25 grams of sausage were taken and suspended in 225 ml of sterile peptonized water (0.1%) and homogenized in a stomacher for 1–2 minutes. Decimal dilutions were prepared, and total mesophilic aerobes (NTE INEN ISO 4833:2014), *E. coli* (NTE INEN ISO 4832:2016), *S. aureus* (AOAC 2003.07), and *Salmonella* (AOAC 2016.01) were counted. The results were evaluated by comparing them with the limits established by current national legislation (NTE INEN 1338-2012). The analysis was performed in duplicate [14].

2.6. Sensory Analysis

Consumer acceptability was evaluated based on the attributes of color, odor, texture, flavor, and overall acceptance. A semi-structured five-point hedonic scale was used. 52 judges were chosen, regardless of gender, who were consumers of sausages and ranged in age between 28 and 40. Samples weighing approximately 20 grams were taken at a temperature of 40 °C and coded with 3 random digits.

2.7. Experimental Design and Statistical Analysis

A completely randomized design was applied in triplicate for weight loss during storage, WRC, and fatty acid profile, and in duplicate for bromatological and microbiological analyses. Results were analyzed with an ANOVA, and means were compared with Fischer's test ($\alpha=0.05$). Statgraphics Centurion software was used [21].

3. Results

Controlling the temperature (45 °C) and the cutting time allowed 20% corn oil to be incorporated without breaking the emulsion. Temperatures higher than 45 °C generated fat loss and emulsion breakage. It is important to point out that no filler or meat extender substance was added to the formulation that could have influenced the stability of the emulsion. The external and internal appearance of the sausages made with back fat and corn oil are shown in Figure 1.

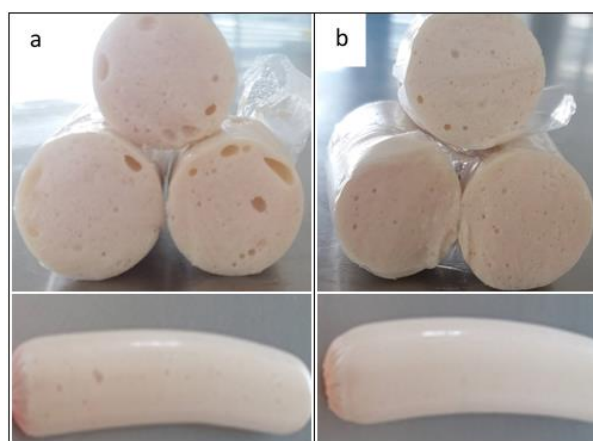


Figure 1. Water Retention Capacity (WRC) and external and internal appearance of sausages made with (a) back fat and (b) corn oil

WRC is one of the most important control parameters in the making of meat products. This property establishes the meat protein's capacity to retain the water of the composition and the water added to the product. It is related to the juiciness and hardness of the sausage. The retention capacity is established with data pertaining to the sausage before and after cooking; during this process, there was no weight loss in the two samples (Table 1). When comparing

the yield values, no significant difference was found between the samples ($p < 0.05$).

Table 1. Yield and weight loss of fiber sample

Sample	Performance (%)	Weight Loss (%)
FT	94.40±0.10	5.60±0.10
CO	93.16±1.15	6.83±1.15

Note: back fat (FT) and corn oil (CO)

Weight loss is a very important parameter at the industrial level. It should be kept below 10%, for which binding agents are often used to aid water retention. The formulations used in this research did not use binding agents. As shown in Figure 2, the weight loss over 20 days of refrigerated storage was 6.8 and 5.6% for CO and FT, respectively.

The bromatological analysis of the sausages is shown in Table 2. The protein content complies with current national legislation (INEN 13338-2012) for a Type I cooked product since it exceeds the minimum total protein content and has no proteins of vegetable origin. Statistical analyses of the CO and FT samples reveal significant differences in protein, moisture, and ash levels, with p -values less than 0.05, indicating that these components vary between the two samples. Specifically, the FT sample exhibits a higher

mean protein content (13.59% vs. 13.18% in CO, $p = 0.0004$) and ash content (3.33% vs. 3.24% in CO, $p = 0.0002$), while the CO sample shows a lower mean moisture content (63.50% vs. 64.66% in FT, $p = 0.026$). However, no significant differences were observed in fat levels between the samples (20.09% in CO vs. 18.68% in FT, $p = 0.068$). These findings suggest that, although both samples share similarities in their fat content, there are important differences in other nutritional and physicochemical components that could influence their quality and functional characteristics.

In a comparative study between sausages made with oil (CO) and fat (FT) (Figure 3), it was observed that CO sausages had a slightly higher pH and elevated peroxide values over time, indicating a greater tendency for lipid oxidation compared to FT sausages. Additionally, CO maintained a slightly higher moisture content. These results are consistent with previous studies suggesting that replacing animal fats with vegetable oils can increase susceptibility to oxidation but does not significantly affect the final product's moisture content [22], [16], [23]. An alternative to improve the $\omega 6/\omega 3$ ratio in sausages with corn oil could be nut, sunflower, or sacha inchi oils, as they are rich in PUFA with high levels of linoleic and lonolenic acid, emphasizing significant differences in the lipid profile compared to animal fats [24].

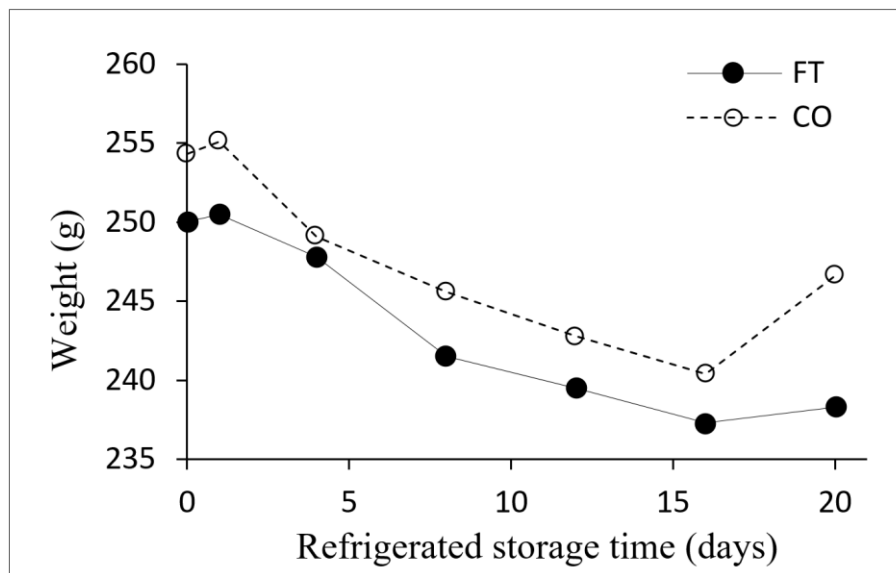


Figure 2. Weight loss of sausages made with back fat and corn oil stored in a refrigerator (4 °C) for 20 days

Table 2. Bromatological analysis of sausages made with back fat (FT) and corn oil (CO)

Muestra	Protein	Fat	Moisture	Ash
CO	13,18±0,02a	20,09±0,12a	63,50±0,10a	3,24±0,006a
FT	13,59±0,07b	18,68±0,97a	64,66±0,57b	3,33±0,01b
p value	0.000444	0.067504	0.025866	0.0002

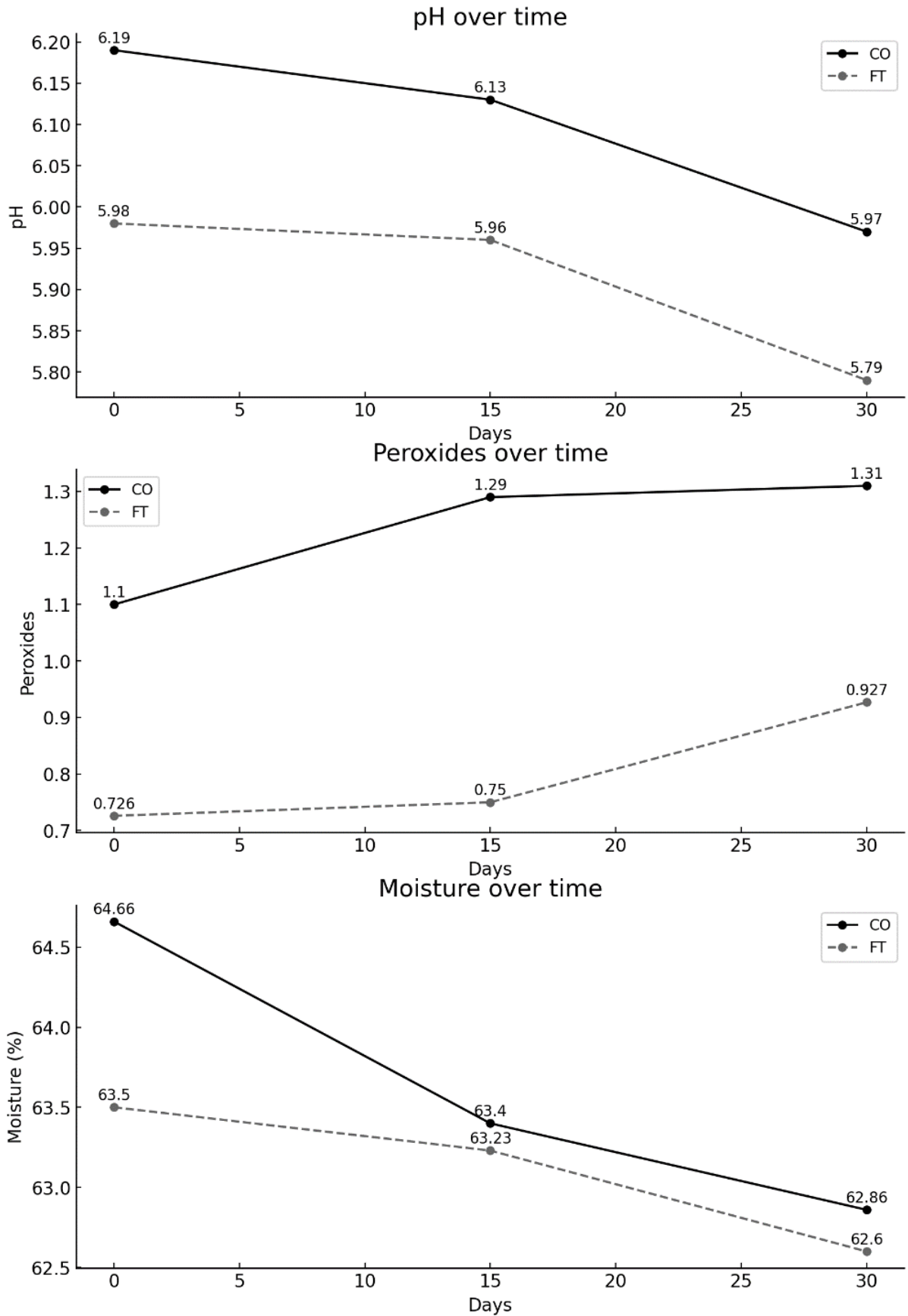


Figure 3. Variation of pH, peroxides, and moisture in Sausages during 30 Days of Refrigerated Storage

The analysis of the microbiological quality of the sausage was carried out at 0, 15, and 30 days of refrigerated storage. During all this time, the samples showed an absence of *Salmonella* and a population of *E. coli* < 10UFC/g. The product is fit for consumption for 30 days after processing, it complied with regulations, maintaining acceptable levels and displaying a slight growth of total mesophilic aerobes that does not exceed the parameters established by INEN 1338-2012 (Table 3).

The fatty acid profile is shown in Table 4. The CO formulation has 20.5% less SFA and 42.2% more PUFA compared to the TF formulation. The CO also had less MUFA (21.8%), thus contributing to improving the content of unsaturated fatty acids and favoring the nutritional content of the product. Significant differences ($p \leq 0.05$) were found between each fatty acid.

Regarding the stearic acid (C18:0) content, an important and significant reduction was found, considering that this FA is only found in animal sources and bibliographic sources report contents of around 5.9% in chicken [25].

The ratio between PUFA and SFA, as well as the omega – 6/omega – 3 ratio, is crucial for health. For CO, the PUFA/SFA ratio is 2,84 and the omega – 6/omega – 3 is 4,79, both within the recommended rangers for cardiovascular and anti-inflammatory benefits [26], [27]. For FT, the PUFA/SFA ratio is 0,33 and the omega –

3/omega-6 ratio is 5,49, indicating a higher risk of cardiovascular and chronic diseases due to the low PUFA/SFA ratio [22].

Table 3. Microbiological analysis of sausages made with back fat (FT) and corn oil (CO)

Microbiological characteristics	Storage time (days)	Formulation	
		FT	CO
APC (FCU/g)	0	< 10	< 10
	15	< 10	< 10
	30	4.4×10^5	3.2×10^5
<i>S. aureus</i> (FCU/g)	0	< 10	< 10
	15	< 10	< 10
	30	< 10	< 10
<i>E. coli</i> (FCU/g)	0	< 10	< 10
	15	< 10	< 10
	30	< 10	< 10
<i>Salmonella</i>	0	N.D.	N.D.
	15	N.D.	N.D.
	30	N.D.	N.D.

APC = aerobic plate count; N.D. = non-detectable

Table 4. Fatty acid profile of sausages made with back fat (FT) and corn oil (CO)

Type of Fatty Acid		CO	FT	p-value
SFA	Caprylic Acid (C8:0)	0.16 ± 0.001^a	0.3 ± 0.006^b	$p < 0.01$
	Capric Acid (C10:0)	0^a	0.4 ± 0.01^b	$p < 0.01$
	Lauric Acid (C12:0)	0^a	0.22 ± 0.21^b	$p < 0.01$
	Myristic Acid (C14:0)	0.13 ± 0.001^a	1.87 ± 0.019^b	$p < 0.01$
	Palmitic Acid (C16:0)	13.88 ± 0.75^a	25.72 ± 0.85^b	$p < 0.01$
	Stearic Acid (C18:0)	2.68 ± 0.07^a	6.89 ± 0.07^b	$p < 0.01$
	Arachidic Acid (C20:0)	1.71 ± 0.015^a	2.09 ± 0.015^b	$p < 0.01$
	Heneicosanoic Acid (C21:0)	0.77 ± 0.02^a	2 ± 0.2^b	$p < 0.01$
	Behenic Acid (C22:0)	0^a	0.26 ± 0.02^b	$p < 0.01$
	Lignoceric acid (C24:0)	0.35 ± 0.04^a	0.41 ± 0.03^a	0,106
MUFA	Palmitoleic Acid (C16:1)	0.87 ± 0.02^a	2.56 ± 0.03^b	$p < 0.01$
	Cis-10-pentadecenoic acid (C15:1)	0.55 ± 0.03^a	0.44 ± 0.04^b	0,0269
	Oleic Acid (C18:1n9cis)	23.3 ± 0.11^a	43.53 ± 0.63^b	$p < 0.01$
PUFA	Linoleic Acid (C18:2n6cis) (Omega 6)	53.99 ± 0.40^a	11.26 ± 0.35^b	$p < 0.01$
	Linolenic Acid (C18:3n3) (Omega 3)	1.57 ± 0.03^a	2.05 ± 0.06^b	0,0002
	SFA	19.58 ± 0.63^a	40.08 ± 1.07^b	$p < 0.01$
	MUFA	24.74 ± 0.15^a	46.53 ± 0.04^b	$p < 0.01$
	PUFA	55.56 ± 0.37^a	13.31 ± 0.41^b	$p < 0.01$

Regarding sensory analysis, no significant difference in acceptance was found between the two sample types (Table 5). The consumer cannot differentiate between the sausage with corn oil and the conventional one with back fat.

Table 5. Sensory characteristics of sausages made with back fat (FT) and corn oil (CO)

Attribute	FT	CO
Color	2.72 ±0.78 ^a	2.76±0.8 ^a
Odor	4.16±0.72 ^a	4.19±0.63 ^a
Taste	4.05 ±0.61 ^a	4.07±0.63 ^a
Texture	4.16 ±0.69 ^a	4.24±0.61 ^a
Overall acceptance	3.77	3.82

4. Discussion

According to other authors, the replacement of back fat with canola, olive, and grape seed oils in emulsion-type pork sausages produced a significant difference in moisture, protein, and fat content. A mixture of oils improved water retention capacity and decreased cholesterol content. Hardness and chewiness decreased significantly, which influences product acceptance, but one of the important benefits is that the amount of unsaturated fatty acids increased [28]. The results of our research show that corn oil produces similar physicochemical characteristics; as an additional contribution, it does not present a significant difference in the sensory analysis, improving consumer acceptance. The incorporation of corn oil also reduces production costs.

A moderate consumption of MUFA is important since they considerably reduce LDL cholesterol levels without modifying HDL cholesterol. In this research, corn oil contributed 9.5% less MUFA than back fat, thus improving the nutritional content of the product [29]. Regarding the content of fatty acids in corn oil, some genetic modifications have been made that improve the amount of fatty acids. A study carried out on fatty acid composition evaluated certain varieties and found non-significant differences in the fatty acid profile. It is worth bearing in mind that the cost of this modification is high [15].

Several studies have shown that greater health benefits are obtained when replacing foods high in SFA with those that contain MUFA and PUFA, thereby reducing cardiovascular risk. Replacing the 5 to 15% energy intake of SFA with PUFA significantly decreases the risk of coronary heart disease (CHD) by 19% [20]. Regarding blood cholesterol, it has been shown that replacing 5% of SFA in the diet with PUFA reduces LDL cholesterol by 5–7% [30] [31]. The sausage developed reduces the SFA content by 20.5%, mainly palmitic and stearic acids, and increases PUFA by 42.2%. Based on scientific evidence, this product contributes to reducing the probability of suffering from CHD and favors the decrease of LDL

cholesterol.

Loss due to cooking is an important parameter when evaluating the physicochemical characteristics of sausages. The corn oil sausage had a cooking loss of 6.83% in 20 days, considering that it had no binding agent and that 100% of the back fat had been replaced. A similar study reported cooking losses of 4% when replacing 50% of the back fat with sunflower oil [32].

Recent research has considered the incorporation of seed oils, such as chia and grape seeds, to replace back fat in meat products. These seeds have a significant contribution of PUFA, although they present problems when forming the emulsion and require binding agents, such as flours and starches, to strengthen the protein mesh. Moreover, the study of the influence of vegetable oil emulsions as fat substitutes indicates that sensory acceptance is a limiting factor that goes beyond the nutritional proposals that are developed [33].

With respect to the shelf life of sausages, it has been demonstrated that by incorporating vegetable oils, which also improve the fatty acid profile and nutritional indexes, the sausages can be conserved for 28 days at temperatures of around 2 °C [34]. We found similar behavior in our investigation: the sausage showed microbiological growth after 30 days of storage at 4 °C.

Sensory acceptance is an extremely important aspect in the development of a product. The replacement of back fat with corn oil did not affect the acceptability of the sausage; no significant differences were found between the formulations ($p \leq 0.05$). In this regard, several authors point out that acceptability is affected with respect to color and flavor due to lipid oxidation despite using microencapsulated fish oil as a PUFA contribution in meat formulations [35]. Likewise, the effect of the food matrix is evident, as pointed out by [36] in tuna and meat sausages with a replacement of up to 4% of oil in the formulation. The products were not well received by consumers, especially those with a higher percentage of both vegetable and animal fat.

5. Conclusions

The replacement of pork back fat with vegetable oils in sausages can have positive effects. However, in many cases, the fat cannot be totally replaced because the technological properties become affected. The addition of vegetable oils decreases the SFA content and increases PUFA and MUFA, which would contribute to the consumption of these sausages being associated with a decrease in chronic noncommunicable diseases. It is vital that the new formulations satisfy the consumer, do not generate losses for the manufacturer, and have a functional contribution. The product developed in this research complies with technological and nutritional quality by decreasing 20.4% of SFA with a 13% protein contribution, meets microbiological quality parameters, generates only a 6.8%

weight loss, and maintains its water retention capacity, being suitable for consumption within 30 days. The research confirms that the total replacement of pork back fat with corn oil in the formulation of sausages is not only technologically possible but also represents a healthy and attractive alternative for the consumer. This breakthrough underscores the importance of continuing to explore innovative alternatives in the processed meat industry in order to offer products that respond to contemporary nutritional needs and the growing demand for healthier foods.

Acknowledgements

We thank the Center for Health Research in Latin America (CISEAL).

REFERENCES

- [1] World Health Organization, "Noncommunicable diseases." Accessed: Feb. 23, 2024. [Online]. Available: <https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases>
- [2] N. Sattar, I. B. McInnes, and J. J. V. McMurray, "Obesity Is a Risk Factor for Severe COVID-19 Infection: Multiple Potential Mechanisms," Jul. 07, 2020, *Lippincott Williams and Wilkins*. doi: 10.1161/CIRCULATIONAHA.120.047659.
- [3] E. Borghi, G. G. Domínguez, and A. Humphreys, "Food Security and Nutrition around the world," in *The State of Food Security and Nutrition in the World 2022*, 2022nd ed., S.-M. J. Pee, Ed., Roma: FAO, 2022, ch. 2, pp. 30–35. doi: 10.4060/cc0639en.
- [4] D. Godoy Gabler *et al.*, "The State of Nutrition: Progress Towards Global Nutrition targets in Latin America and the Caribbean," in *Regional Overview of Food Security and Nutrition – Latin America and the Caribbean 2022*, 2022nd ed., C.-C. G.-C. V. Holleman, Ed., Santiago: FAO; IFAD; UNICEF; PAHO; WFP, 2023, ch. 2, pp. 21–29. doi: 10.4060/cc3859en.
- [5] OPS and OMS, "Pan American Health Organization," For greater effectiveness and equity: a cross-sectoral response to address noncommunicable diseases from the social determinants of health. Accessed: Feb. 24, 2024. [Online]. Available: <https://www.paho.org/es/noticias/3-3-2023-para-mayor-efectividad-equidad-respuesta-intersectorial-para-abordar-enfermedades>
- [6] Á. Puyol, "Ética, equidad y determinantes sociales de la salud," *Gac Sanit*, vol. 26, no. 2, pp. 178–181, Mar. 2012, doi: 10.1016/j.gaceta.2011.08.007.
- [7] C. Cabezas, B. Hernández, and M. Vargas, "Fat and oils: Effects on health and global regulation," *Revista de la Facultad de Medicina*, vol. 64, no. 4, pp. 761–768, Mar. 2016.
- [8] N. De Wit *et al.*, "Saturated fat stimulates obesity and hepatic steatosis and affects gut microbiota composition by an enhanced overflow of dietary fat to the distal intestine," *Am J Physiol Gastrointest Liver Physiol*, vol. 303, pp. 589–599, Jun. 2012, doi: 10.1152/ajpgi.00488.2011.-We.
- [9] A. Miranda, C. Gómez-Gaete, and S. Mennickent, "Role of Mediterranean diet on the prevention of Alzheimer disease," *Rev Med Chil*, vol. 145, no. 7, pp. 501–507, Jul. 2017, doi: <http://dx.doi.org/10.4067/S0034-98872017000400010>.
- [10] L. A. Profenno, A. P. Porsteinsson, and S. V. Faraone, "Meta-analysis of Alzheimer's disease risk with obesity, diabetes, and related disorders," *Biol Psychiatry*, vol. 67, no. 6, pp. 505–512, Mar. 2010, doi: 10.1016/j.biopsych.2009.02.013.
- [11] W. Freire *et al.*, "Food consumption," in *National Health and Nutrition Survey of the Ecuadorian Population from 0 to 59 years. ENSANUT-ECU-2012*, 1st ed., vol. Tomo 1, no. 1, Quito - Ecuador: Ministry of Public Health/National Institute of Statistics and Censuses, 2014, ch. XII, pp. 313–321.
- [12] F. Bravo and P. Pozo, "Determination of fatty acids profile in sausages and mayonnaise of highest consumption in the Metropolitan District of Quito by gas chromatography," *Infoanal fica*, vol. 3, Quito, pp. 41–52, Oct. 2015.
- [13] INEN Ecuadorian Institute of Standardization, "Meat and meat products. Sausages. Requirements," Quito - Ecuador, Nov. 1996.
- [14] INEN - Ecuadorian Institute of Standardization, "Meat and meat products. raw meat products, cured - matured meat products, and precooked - cooked meat products. Requirements.," Quito - Ecuador, Mar. 2012.
- [15] C. Delucchi, N. M. Percibaldi, M. Trejo, and G. Eyherabide, "Genetic improvement of the fatty acid profile of corn oil.," *Journal of Agricultural Research*, Argentina, pp. 159–181, Aug. 15, 2019.
- [16] H.-J. Lee, Eun-Hee Jung, L. Sang-Hwa, K. Jong-Hee, L. Jae-Joon, and Y. Cho, "Effect of replacing pork fat with vegetable oils on quality properties of emulsion-type pork sausages," *Korean J Food Sci Anim Resour*, vol. 35, no. 1, pp. 130–136, Feb. 2015, Accessed: Jan. 16, 2024. [Online]. Available: DOI.org/10.5851/kosfa.2015.35.1.130
- [17] AOAC International, "Method 925.10: Determine moisture," in *Official Methods of Analysis of AOAC International*, 22nd ed., vol. 3, AOAC International, Ed., Oxford: AOAC International, 2023, ch. 925.10.
- [18] AOAC International, "Method 923.02: Determine Ash," in *Official Methods of Analysis of AOAC International*, 22nd ed., vol. 3, AOAC International, Ed., Oxford: AOAC International, 2023, ch. ash (923.02).
- [19] AOAC International, "Method 2001.11: Determine Protein," in *Official Methods of Analysis of AOAC International*, 22nd ed., vol. 3, AOAC International, Ed., Oxford: AOAC International, 2023, ch. 2001.11.
- [20] AOAC International, "Method 2003.06: Determine Fat," in *Official Methods of Analysis of AOAC International*, 22nd ed., vol. 3, AOAC International, Ed., Oxford: AOAC International, 2023, ch. 2003.06.
- [21] Inc. Statgraphics Technologies, "STATGRAPHICS 19 Centurion," Apr. 2023, *Statgraphics Technologies, Inc.*,

The Plains, Virginia: 19.

- [22] A. H. Mariamenatu and E. M. Abdu, "Overconsumption of Omega-6 Polyunsaturated Fatty Acids (PUFAs) versus Deficiency of Omega-3 PUFAs in Modern-Day Diets: The Disturbing Factor for Their 'Balanced Antagonistic Metabolic Functions' in the Human Body," *J Lipids*, vol. 2021, pp. 1–15, Mar. 2021, doi: 10.1155/2021/8848161.
- [23] G. M. Monteiro, X. R. Souza, D. P. B. Costa, P. B. Faria, and J. Vicente, "Partial substitution of pork fat with canola oil in Toscana sausage," *Innovative Food Science & Emerging Technologies*, vol. 44, pp. 2–8, Dec. 2017, doi: 10.1016/j.ifset.2017.07.013.
- [24] S. Yanti, D. S. Saputri, H. Y. Lin, Y. C. Chou, D. C. Agrawal, and W. J. Chien, "Fatty acid evaluation of seeds and nuts by spectroscopy and chromatography," *Food Science and Technology*, vol. 9, no. 3, pp. 58–68, 2021, doi: 10.13189/fst.2021.090302.
- [25] A. S. Torquato *et al.*, "Fatty acid profile of meat from broiler chickens fed with different oil sources," *Archivos de Zootecnia*, vol. 67, no. 260, pp. 532–540, Oct. 2018.
- [26] A. P. Simopoulos, "The importance of the ratio of omega-6/omega-3 essential fatty acids," *Biomedicine & Pharmacotherapy*, vol. 56, no. 8, pp. 365–379, Oct. 2002, doi: 10.1016/S0753-3322(02)00253-6.
- [27] A. P. Simopoulos, "The Importance of the Omega-6/Omega-3 Fatty Acid Ratio in Cardiovascular Disease and Other Chronic Diseases," *Exp Biol Med*, vol. 233, no. 6, pp. 674–688, Jun. 2008, doi: 10.3181/0711-MR-311.
- [28] K. H. Baek, D. T. Utama, S. G. Lee, B. K. An, and S. K. Lee, "Effects of replacing pork back fat with canola and flaxseed oils on physicochemical properties of emulsion sausages from spent layer meat," *Asian-Australas J Anim Sci*, vol. 29, no. 6, pp. 865–871, Jun. 2016, doi: 10.5713/ajas.15.1050.
- [29] R. Micha *et al.*, "Global, regional, and national consumption levels of dietary fats and oils in 1990 and 2010: A systematic analysis including 266 country-specific nutrition surveys," *Br Med J*, vol. 348, Apr. 2014, doi: 10.1136/bmj.g2272.
- [30] E. Ros *et al.*, "Consensus on fats and oils in the diet of the Spanish adult population; position of the Spanish Federation of Societies of Food, Nutrition and Dietetics (FESNAD)," *Nutr Hosp*, vol. 32, no. 2, pp. 435–477, 2015, doi: 10.3305/nh.2015.32.2.9202.
- [31] R. P. Mensink, P. L. Zock, A. D. Kester, and M. B. Katan, "Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: a meta-analysis of 60 controlled trials," *Am J Clin Nutr*, vol. 77, pp. 1146–55, 2003, doi: 10.1093/ajcn/77.5.1146.
- [32] J. Pereira, S. A. Brohi, S. Malairaj, W. Zhang, and G. H. Zhou, "Quality of fat-reduced frankfurter formulated with unripe banana by-products and pre-emulsified sunflower oil," *Int J Food Prop*, vol. 23, no. 1, pp. 420–433, Jan. 2020, doi: 10.1080/10942912.2020.1733014.
- [33] F. A. L. De Carvalho *et al.*, "Effect of replacing backfat with vegetable oils during the shelf-life of cooked lamb sausages," *LWT - Food Science and Technology*, vol. 122, pp. 1–10, Mar. 2020, doi: 10.1016/j.lwt.2020.109052.
- [34] M. Momchilova, D. Gradinarska-Ivanova, T. Petrova, and D. Yordanov, "Influence of emulsions of vegetable oils as fat substitutes on the colour and sensory quality of cooked sausages during storage," in *IOP Conference Series: Earth and Environmental Science*, Honolulu: Institute of Physics, Apr. 2022, p. 1052. doi: 10.1088/1755-1315/1052/1/012078.
- [35] R. Domínguez, M. Pateiro, R. Agregán, and J. M. Lorenzo, "Effect of the partial replacement of pork backfat by microencapsulated fish oil or mixed fish and olive oil on the quality of frankfurter type sausage," *J Food Sci Technol*, vol. 54, no. 1, pp. 26–37, Jan. 2017, doi: 10.1007/s13197-016-2405-7.
- [36] A. García, P. Izquierdo, S. Uzcátegui-Bracho, J. F. Farfán, M. Allara, and A. C. García, "The tuna and beef formulate sausage: Its life span and acceptability," *Revista Científica-Facultad De Ciencias Veterinarias*, vol. 15, no. 3, pp. 272–278, 2005, Accessed: May 16, 2024. [Online]. Available: <http://www.redalyc.org/articulo.oa?id=95915311>