Foods 2021

MDPI

Proceeding Paper

Assessment of Total and Partial Fat Replacement in Frankfurt-Type Sausages by Gelled Emulsion Elaborated with Peanut Flour and Flax Oil. Effect on Chemical Composition, Physico-Chemical and Sensorial Properties †

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† Presented at the 2nd International Electronic Conference on Foods, 15–30 October 2021; Available online: https://foods2021.sciforum.net/.

Abstract: A gelled emulsion (GE) prepared with flax oil and peanut flour was used to replace pork back-fat in Frankfurt-type sausages. Three different formulations were prepared: Control (CS) with 30% pork back fat), and the following two to achieve 50% and 100% fat substitution by GE (GE50 and GE100, respectively). This study demonstrated that the use of gelled emulsion elaborated with peanut flour and flax oil may be a promising strategy in the reformulation of healthier meat products due to produce a reduction in fat content and improve the fatty acid profile.

Keywords: reformulation; gelled emulsion; cooked meat products; vegetable oils; fat replacer

Citation: Botella-Martínez, C.; Sayas-Barberá, E.; Pérez-Alvarez, J.Á.; Fernández-López, J.; Viuda-Martos M. Assessment of Total and Partial Fat Replacement in Frankfurt-Type Sausages by Gelled Emulsion Elaborated with Peanut Flour and Flax Oil. Effect on Chemical Composition, Physico-Chemical and Sensorial Properties. *Foods2021* **2021**, *1*, x, https://doi.org/10.3390/xxxxx

Published: date

1. Introduction

Frankfurter type sausages are one of the most consumed meat products worldwide. Among the reasons that make this product so popular are its taste, convenience and low price. On the other hand, this meat product contains a high amount of fat, exceeding 40% in some formulations [1]. This makes the consumer, increasingly aware of the relationship between food and health, begins to reject this type of product. The food industry is known to this problem and must adapt and offer the consumer products according to their needs and concerns. One of the strategies followed by the food industry to get closer to the products demanded by the consumer is the development of products with low fat content or with a healthier lipid profile compared to traditional formulations [2]. Thus, the aim of this work was to determine the effect of the partial and total replace of pork backfat, by a gelled emulsion elaborated with peanut flour and flaxseed oil, on chemical composition, physic-chemical and sensorial properties of Frankfurt-type sausages.

2. Material and Methods

2.1. Materials

The ingredients used to make gelled emulsions were: flaxseed oil (53.82% linolenic acid, 15.74% linoleic acid, 19.32 oleic acid, 5.61% palmitic acid and 4.04% stearic acid) from Laboratorios Almond, S.L. (Murcia, Spain); peanut flour distributed by Buffsupp sport nutrition (Batley, UK); and gelatin from animal origin (pork) with 180 bloom that was supplied from Sosa Ingredients S.L. (Barcelona, Spain).

2.2. Elaboration of Oil-in-Water-Gelled Emulsion

Oil in water gelled emulsions (GE) were elaborated following the recommendation of Öztürk-Kerimoğlu et al. [3].

2.3. Elaboration of Frankfurt-Type Sausages

Frankfurter-type sausages were elaborated according to the formula described by Botella-Martínez et al. [4]. Three independent replicates of each batch were prepared. The traditional formula was used as control sample (CS) and the other two batches were formulated replacing the animal fat by the GE previously prepared: 50% of pork backfat was replace by GE (GE50) and 100% of pork backfat was replace by GE (GE100).

2.4. Proximate Composition of Franckfurt-Type Sausages

The chemical composition (moisture, protein, fat, and ash content) of samples was analyzed according to the Association of Official Analytical Chemist analysis [5].

2.5. Fatty Acid Composition

Lipid extraction of Frankfurter was done following the methodology described by Bligh and Dyer. Gas Chromatography (GC) analysis were carried out to determine the fatty acid profile using the methodology described by Pellegrini et al. [6].

2.6. Physic-Chemical Properties

The pH values of samples was assessed directly using a Crison combination electrode probe connected to a pH meter (model 507 Crison, Barcelona, Spain). Texture profile analysis was performed using a texture analyzer TA-XT2 (Stable Micro Systems, Farncombe, UK) following the methods for the objective measurement of meat product texture [7]. The color was studied in the CIEL*a*b* color space using a Minolta CM-700 (Minolta Camera Co., Osaka, Japan). The CIEL*a*b* coordinates determined were: lightness (L*), redness (a*, coordinate red/green), and yellowness (b*, coordinate yellow-blue). Emulsion stability of samples (before heat treatment) was assessed by means of total expressible fluid (TEF) following the recommendations of Pintado et al. [2]

2.7. Lipid Oxidation

Lipid oxidation of samples was determined by the 2-thiobarbituric acid (TBA) method following the recommendations of Rosmini et al. [8]. The lipid oxidation values were expressed as mg malondialdehyde (MDA)/kg sample.

2.8. Sensory Analysis

A 50-member sensory panel with no specific training in the sensory analysis of Frankfurt sausages was recruited from the staff and students of the Miguel Hernández University. Pieces of 2.0 cm (3 pieces, one from each bath) were cut from the frankfurter and served at room temperature. Unsalted crackers and mineral water were provided to clean the palate between samples. The hedonic scale contained 7 levels (9 = highly acceptable; 1 = highly unacceptable), in which the panelists evaluated the nest parameters: color, brightness, salty flavor, fattiness, juiciness, hardness, and general acceptability.

2.9. Statistical Analysis

All assays were done in triplicate and the data were stated as mean ± standard deviation and compared through statistical program NCSS (2011 version) software. The analysis of the data consisted one-way analysis of variance (ANOVA), the effects of the treatment were considered. The Tukey's post hoc test was applied for comparisons of means and differences were considered significant at $p < 0.05$.

3. Results and Discussion

3.1. Chemical Composition

Table 1 showed the chemical composition of Frankfurt-type sausage formulates replacing pork backfat by gelled emulsion elaborated with peanut flour and flaxseed oil. As regards to protein and as content, no statistical differences ($p > 0.05$) were found between CS and GE50 and GE100. For moisture, GE100 had the highest ($p < 0.05$) values while no differences ($p > 0.05$) were obtained for CS and GE50.

Table 1. Chemical composition of Frankfurt-type sausage formulates replacing pork backfat by gelled emulsion elaborated with peanut flour and flaxseed oil.

Sample	Moisture	Protein	Fat	Ash
CS	60.65 ± 0.81 ^{b}	16.29 ± 0.17 ^{a}	16.69 ± 0.28 ^{a}	2.19 ± 0.19 ^{a}
GE50	60.56 ± 0.30 ^{b}	16.18 ± 0.12 ^{a}	13.81 ± 0.79 ^{b}	1.97 ± 0.11 ^{a}
GE100	62.49 ± 0.25 ^{a}	16.56 ± 0.01 ^{a}	11.77 ± 0.56 ^{c}	2.14 ± 0.07 ^{a}

Values expressed as g/100 g. CS: Control sample; GE50: Frankfurt sausage where the fat was replaced with a gelled emulsion of 50%; GE100: Frankfurt sausage where the fat was replaced with a gelled emulsion of 100%. Values with the same letter in the same column indicates no significant differences according to Tukey's HSD post-hoc test ($p > 0.05$).

In the case of fat content, a substantial reduction ($p < 0.05$) in total fat content was obtained in Frankfurt sausages as the level of fat replacement by gelled emulsion increased. This reduction is similar than reported by Botella-Martínez et al. [4] in Frankfurters prepared with gelled emulsion elaborated with vegetables oils and pseudocereal flours. In reference to fatty acid profile (Table 2), the results achieved shown that the fatty acid profile was affected by the fat replacement by gelled emulsion.

Table 2. Fatty acid profile of Frankfurt-type sausage formulates replacing pork backfat by gelled emulsion elaborated with peanut flour and flaxseed oil.

Fatty Acid Profile	CS	GE50	GE100
C12:0	0.08 ± 0.00 ^{a}	0.06 ± 0.00 ^{b}	0.03 ± 0.00 ^{c}
C14:0	1.31 ± 0.00 ^{a}	1.01 ± 0.00 ^{b}	0.51 ± 0.00 ^{c}
C15:0	0.04 ± 0.00 ^{a}	0.04 ± 0.00 ^{a}	0.03 ± 0.00 ^{a}
C16:0	23.43 ± 0.04 ^{a}	19.04 ± 0.03 ^{b}	11.57 ± 0.01 ^{c}
C16:1n-7	2.24 ± 0.01 ^{a}	1.63 ± 0.00 ^{b}	0.98 ± 0.01 ^{c}
C17:0	0.32 ± 0.00 ^{a}	0.25 ± 0.00 ^{b}	0.15 ± 0.00 ^{c}
C17:1n-7	0.38 ± 0.00 ^{a}	0.31 ± 0.01 ^{b}	0.12 ± 0.00 ^{c}
C18:0	12.22 ± 0.02 ^{a}	10.13 ± 0.02 ^{b}	6.77 ± 0.00 ^{c}
C18:1n-9	49.25 ± 0.03 ^{a}	42.72 ± 0.11 ^{b}	28.90 ± 0.05 ^{c}
C18:2n-6	5.63 ± 0.00 ^{c}	8.17 ± 0.02 ^{b}	13.32 ± 0.02 ^{a}
C18:3n-3	0.34 ± 0.00 ^{c}	12.35 ± 0.08 ^{b}	34.51 ± 0.06 ^{a}
C20:0	0.21 ± 0.00 ^{a}	0.20 ± 0.00 ^{a}	0.19 ± 0.00 ^{b}
C20:1n-9	1.05 ± 0.01 ^{a}	0.91 ± 0.02 ^{b}	0.39 ± 0.00 ^{c}
C20:2	0.29 ± 0.01 ^{a}	0.24 ± 0.01 ^{b}	0.14 ± 0.00 ^{c}
C20:3n-11	0.35 ± 0.00 ^{a}	0.31 ± 0.00 ^{b}	0.28 ± 0.00 ^{c}
C24:0	0.07 ± 0.01 ^{a}	0.07 ± 0.01 ^{a}	0.07 ± 0.02 ^{a}

Values expressed as g/100 g fat. CS: Control sample; GE50: Frankfurt sausage where the fat was replaced with a gelled emulsion of 50%; GE100: Frankfurt sausage where the fat was replaced with a gelled emulsion of 100%. Values with the same letter in the same row indicates no significant differences according to Tukey's HSD post-hoc test ($p > 0.05$).

All samples the samples analyzed presented significant differences ($p < 0.05$) in the content of saturated, monounsaturated, and polyunsaturated fatty acids with respect to

the control sample. In control sample, the monounsaturated and saturated fatty acids were the predominant groups with oleic acid, palmitic acid and stearic acid as the major compounds. On the other hand, GE50 and GE100 increased the polyunsaturated fatty acids, mainly linoleic acid (C18:2n-6) and linolenic (C18:3n-3) and did it a dependent-manner on the degree of replacement. These results were in agreement with those reported by Nacak et al. [9] who reported a reduction in saturated and monounsaturated fatty acids and an increase of polyunsaturated fatty acids in the fatty acid profile of emulsified sausages elaborated with flaxseed oil.

3.2. Physic-Chemical Properties

Emulsion stability (%TEF), pH, and color parameters are shown in Table 3. In reference to emulsion stability, the higher the %TEF, the lower emulsion stability. The pork backfat substitution by GE50 and GE100 (at any percentage) caused significant differences ($p < 0.05$) in emulsion stability. Thus, the GE100 had the lowest ($p < 0.05$) emulsion stability values. This effect could be explained as mentioned de Souza Paglarini et al. [10] due to a reduction on animal fat content in cooked meat products, like sausages, reduce their stability. All Frankfurt-Type sausages had a pH values in the range considered normal for this type of cooked sausages [11] with statistical differences ($p < 0.05$) between samples. For All color parameters (L*, a*, b*) were significantly ($p < 0.05$) affected by the use of GE as fat replacer in Frankfurt-type sausages. Thus, EG100 showed the highest ($p < 0.05$) L*, a*, b* values. These values were, probably, due to the differences in color between pork back fat and the GE used as replacers [12].

Table 3. Physic-chemical properties of Frankfurt-type sausage formulates replacing pork backfat by gelled emulsion elaborated with peanut flour and flaxseed oil.

			Color Parameter		
Sample	**%TEF**	**pH**	**L***	**a***	**b***
CS	3.56 [c]	6.29 ± 0.01 [a]	61.21 ± 0.51 [c]	4.55 ± 0.28 [c]	10.17 ± 0.65 [c]
GE50	6.94 [b]	6.20 ± 0.01 [b]	62.96 ± 0.63 [b]	5.39 ± 0.21 [b]	13.75 ± 0.78 [b]
GE100	9.90 [a]	6.12 ± 0.05 [b]	63.40 ± 0.36 [a]	5.83 ± 0.20 [a]	17.40 ± 0.65 [a]
			Texture Properties		
Sample	**Hardness (N)**	**Springiness (mm)**	**Cohesiveness**	**Chewiness (N × mm)**	
CS	59.72 ± 1.99 [a]	0.30 ± 0.04 [a]	0.52 ± 0.09 [a]	9.14 ± 0.32 [a]	
GE50	54.29 ± 1.74 [b]	0.31 ± 0.04 [a]	0.55 ± 0.03 [a]	8.16 ± 0.40 [b]	
GE100	50.14 ± 1.25 [c]	0.33 ± 0.04 [a]	0.50 ± 0.06 [a]	8.09 ± 0.56 [b]	

CS: Control sample; GE50: Frankfurt sausage where the fat was replaced with a gelled emulsion of 50%; GE100: Frankfurt sausage where the fat was replaced with a gelled emulsion of 100%. Values with the same letter in the same column indicates no significant differences according to Tukey's HSD post-hoc test ($p > 0.05$).

Texture (Table 3) is other very important factor for consumers in reference to meat products. The backfat replacement by GE had no effect ($p < 0.05$) on springiness and cohesiveness. For these parameters, no statistical differences were found between CS and GE50 and GE100. However, the replacement of fat by GE in sausage formulation produces a significantly decreased ($p < 0.05$) in the hardness of the samples which is dependent of replacement degree. The higher the substitution, the lower the hardness. These results were opposite than those reported by Pintado et al. [2] or Nacak et al. [9] Who mentioned that sausages increased the hardness when increased the fat replacement by gelled emulsion due to lipid-protein interactions.

3.3. Lipid Oxidation

The lipid oxidation values of Frankfurt-type sausages formulates replacing pork backfat by gelled emulsion elaborated with peanut flour and flaxseed oil are shown in

Figure 1. Control sample had the lowest ($p < 0.05$) values being the GE100 which showed the highest ($p < 0.05$) oxidation degree. The results obtained showed that the animal fat replacement by gelled emulsions had an undesirable effect on the oxidative stability of sausages. This phenomenon could be explained due to the substitution of saturated fatty acids, present in animal fat, which are more stable to oxidation, with unsaturated fatty acids present in vegetable oils, which are more susceptible to lipid oxidation as mentioned Lucas-Gonzalez et al. [13].

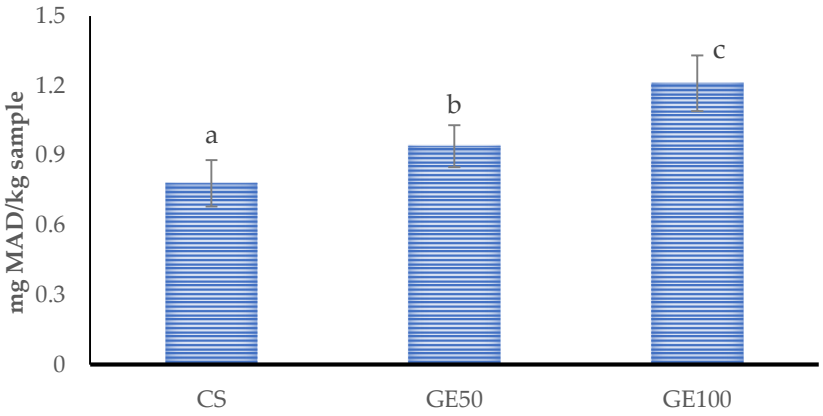

Figure 1. Lipid oxidation values (mg malonaldehyde/kg sample) of Frankfurt-type sausages formulates replacing pork backfat by gelled emulsion elaborated with peanut flour and flaxseed oil. CS: Control sample; GE50: Frankfurt sausage where the fat was replaced with a gelled emulsion of 50%; GE100: Frankfurt sausage where the fat was replaced with a gelled emulsion of 100%. Values with the same letter in the same bars indicates no significant differences according to Tukey's HSD post-hoc test ($p > 0.05$).

3.4. Sensorial Analysis

Figure 2 showed the results obtained for the sensorial analysis carried out in Frankfurt-type sausages formulates replacing pork backfat by gelled emulsion elaborated with peanut flour and flaxseed oil. According to the results, it was shown that color, salty flavor, fattiness, juiceness, and hardness did not present significant differences ($p > 0.05$) between GE50 and the control sample. GE100 had the lowest scores ($p < 0.05$) in all parameters analyzed.

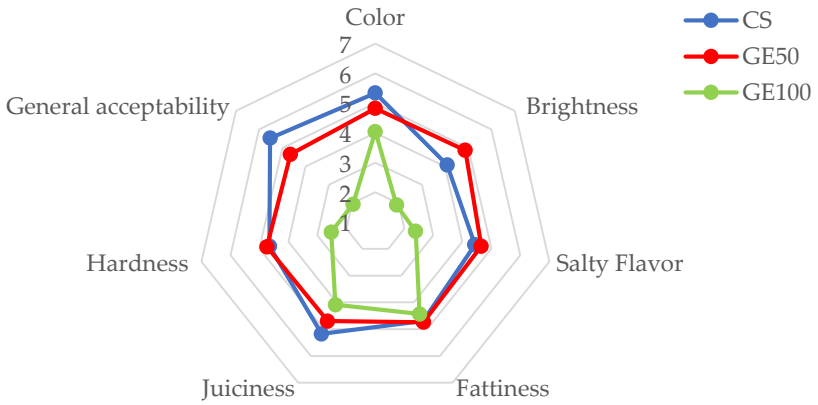

Figure 2. Sensorial parameters of Frankfurt-type sausages formulates replacing pork backfat by gelled emulsion elaborated with peanut flour and flaxseed oil. CS: Control sample; GE50: Frankfurt sausage where the fat was replaced with a gelled emulsion of 50%; GE100: Frankfurt sausage where the fat was replaced with a gelled emulsion of 100%.

4. Conclusions

This study demonstrated that the use of gelled emulsion elaborated with peanut flour and flax oil may be a promising strategy in the reformulation of healthier meat products due to the texture properties and lipid stability, despite being modified, are within the parameters that can be considered normal. On the other hand, the sausages had a better lipid profile with higher content of polyunsaturated fatty acids which increased omega 3 amount and reduced saturated fatty acids.

Author Contributions: Conceptualization, M.V.-M.; Methodology and investigation, C.B.-M.; data curation E.S.-B. Formal analysis and writing—original draft preparation J.F.-L. Writing—review and editing, J.Á.P.-A. and M.V.-M. All authors have read and agreed to the published version of the manuscript

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data presented in this study are available on request from the corresponding author.

Acknowledgments: All researchers are members of the HealthyMeat network, funded by CYTED (ref: 119RT0568).

Conflicts of Interest: The authors declare no conflict of interest.

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