PE9.20 Nutritional properties of potential functional frankfurter with healthier lipid profile, seaweed and low salt content 125.00

Susana Cofrades (1) scofrades@if.csic.es, Inés López-López(1), Claudia Ruiz-Capillas (1), Francisco Jiménez-Colmenero (1)
(1)Instituto Del Frio (CSIC)

Abstract— **The aim of this paper is to analyse the nutritional composition (protein, fat, ash, dietary fibre, fatty acid profile and sodium and potassium content) of low-fat frankfurters enriched with algal oil (rich in *docosahexaenoic acid*-DHA) as affected by the addition of seaweed (5.5 % *Himanthalia elongata*) and the partial substitution (50 %) of animal fat by olive oil or combinations of olive oil and seaweed. Reduction of NaCl level is also studied. The presence of algal oil produced frankfurters with high polyunsaturated fatty acids (PUFA) content. The partial substitution of the pork fat by olive oil reduced (P<0.05) saturated fatty acids (SFA) and promoted (P<0.05) monounsaturated fatty acids (MUFA). A healthier lipid formulation (algal and olive oils and the reducing animal fat) produced a good balance of MUFA/SFA, PUFA/SFA and n-6/ n-3 ratios. Seaweed addition does constitute a means to produce low-sodium products with important dietary fibre content and with better Na/K ratios.**

I. López-López is with the Instituto del Frío (C.S.I.C.), Madrid, Spain (e-mail: ilopez@if.csic.es).
*S. Cofrades is with the Instituto del Frío (C.S.I.C.), Madrid, Spain (corresponding author; phone: +34 915492300; fax:+34915493627; e-mail: scofrades@if.csic.es).
C. Ruiz-Capillas is with the Instituto del Frío (C.S.I.C.), Madrid, Spain (e-mail: Claudia@if.csic.es).
F. Jiménez-Colmenero is with the Instituto del Frío (C.S.I.C.), Madrid, Spain. (e-mail: fjimenez@if.csic.es).

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I. INTRODUCTION

Seaweeds contain various bioactive compounds with potential health-beneficial properties, and hence their use as functional ingredients opens up new possibilities in food processing, including meat products [1], [2]. Edible seaweeds contain acceptable amounts of protein, and their amino acid composition is of nutritional interest, they are also an excellent source of most minerals and dietary fibre [1]. Algal lipids (1-3% dry matter) contain a high proportion of essential fatty acids, particularly long chain n-3 PUFA and they also contain bioactive compounds with known antioxidant properties [1]. The high concentrations of mineral elements in seaweeds suggest the possibility of using them to reduce the amount of added NaCl in meat processing. Since sodium intake generally exceeds nutritional recommendations, there is increasing interest among consumers and processors in reducing the use of salt (minimizing sodium) in meat processing. Very little attention has been paid to the use of edible seaweeds as ingredients in meat products. Chun et al. [3] studied the quality characteristics of hamburger patties with 1-5 g/100 g seaweed powder (*Sagassum thunbergii* or *Gelidium amansii*). Cofrades et al. [2] evaluated the effects of three different types of edible seaweeds, Sea Spaghetti (*Himanthalia elongata),* Wakame (*Undaria pinnatifida),* and Nori (*Porphyra umbilicalis*), on the physicochemical and structural characteristics of gel/emulsion meat systems. They suggested that the use of these algae in meat products opens up interesting prospects for the use of seaweeds in the formulation of healthier meat products to overcome technological problems associated with low-salt products.

Lipids are among the bioactive components that have received most attention, particularly with respect to the development of healthier meat products [4]. Based on recommendations for optimal intake of total and unsaturated fatty acids, the modification of lipid fractions in meat products has been concerned chiefly with reducing fat content and improving fatty acid profiles. This is of particular interest in products like frankfurter sausages, which normally possess high fat contents and lipid profiles diverging from dietary goals. Olive, is one the vegetables oils that has received most attention, mainly as a source of MUFA. Marine oils (fish and algal oil), have been used to supply substantial amounts of n-3 PUFAs in order to produce long chain n-3 PUFA-enriched meat products [5], [6]. In previous studies, [7] have shown that addition of algal oil, olive oil and seaweed on low-fat frankfurters presented adequate technological and sensory properties as well as chilling stability. Also, these authors assessed the nutritional composition of potential functional frankfurters [8]. This paper presents some interesting aspects about nutritional composition of these products: low-fat and n−3 PUFA-enriched frankfurter (400 mg DHA/100 g product) as affected by the addition of seaweed (5% *Himanthalia elongata*), partial substitution (50%) of animal fat by olive oil or combinations of olive oil and seaweed. Reduction of NaCl levels is also studied.

II. MATERIALS AND METHODS

A. Meat raw materials, non-meat ingredients and frankfurter manufacture

Meat raw material (post-rigor pork meat and pork back fat) and Sea Spaghetti, (collected on the northwest Iberian coast), were prepared as described by [2]. Extra virgin olive oil (13 % SFA, 79 % MUFA and 8 % PUFA) (Carbonell, Cordoba. Spain) and algal oil DHA^{TM}-S (DHA content ≥ 350 mg/g oil) (Marteck Biosciences, Co., Columbia, USA) were used. Four different frankfurter formulations were prepared [8] and the formulation of these products is shown in Table 1.

B. Proximate analysis

Moisture and ash contents were determined [9], in triplicate. LECO FP-2000 Nitrogen Determinator (Leco Corporation, St Joseph, MI, USA) was used to determine the protein content in triplicate. Fat content was evaluated (in triplicate) according to Bligh and Dyer [10]. Dietary fibre was estimated from Sea Spaghetti dietary fibre content [2].

C. Fatty acid profile

Fatty acids were determined in three lipid extractions of each sample by gas chromatography. Boron trifluoride/methanol was used to prepare fatty acid methyl esters (FAME), according to [11]. A Shimadzu gas chromatograph (Model GC-2014, Kyoto, Japan) fitted with a capillary column SP^{TM}-2330 (60M X 0.25 MM X 0.2μM) and a flame ionization detector (FID) was used. Fatty acids were expressed as a percentage of the total FAME. When necessary quantification was done by normalization and transformation of the area percentage into mg/100g of edible portion, using the lipid conversion factor to pork fat and oils [12].

D. Sodium, potassium and calcium content

Na and K content were analysed by atomic emission as described [8].

E. Statistical analysis

Data were analysed using Statgraphics Plus 5.1 (STSC Inc. Rockville, MD, USA). The effect of each formulation was tested by ANOVA one-way. Tukey test was used to identify significant differences ($P<0.05$) among means.

III. RESULTS AND DISCUSSIONS

A. Proximate analysis

Protein content of frankfurters ranged between 15.32 and 17.38 % (Figure 1). While C and O samples contained only meat protein, S and OS samples also contained a small amount of Sea Spaghetti protein [2]. Fat content of samples, ranged between 12.0-13.2 %, which is lower than those normally found in commercial frankfurters. The variations between ash levels in samples, which ranged from 2.93 % and 3.73 % (Table 1), may be attributed to the addition of the seaweed (Figure 1) which contains over 30 % ash dry matter [2]. On the other hand, this seaweed contains over 50 % total dietary fibre [2], so the addition of 5.5 % Sea Spaghetti would supply over 2.5 % of total dietary fibre to frankfurters. The incorporation of dietary fibre into commonly consumed foods like the meat products formulated in this experiment could help correct the deficiency of the Spanish consumers (as other Europeans) that generally consume around 20 g/day [13], versus more than 25 g/day as recommended [14]. Consumption of 100 g of frankfurters with added seaweed supplies around 10 % of the recommended daily dietary fibre intake.

B. Fatty acid profile

The fatty acid composition of the frankfurters was affected by the type of formulation (Table 2). SFA content was higher ($P<0.05$) in control and S products (Table 2) while MUFA content was higher ($P<0.05$) in products with olive oil (over 57% in O and OS samples) as compared with C and S samples, meaning a higher MUFA/SFA ratio (Table 2). The oleic acid was the most abundant fatty acid in all frankfurters and this was consistent with the lipid profile of the olive oil. Since algal oil was added in all the frankfurters, the DHA content was higher than in common pork frankfurter and also produced higher levels of PUFA in all frankfurters than those normally found in products of a similar nature formulated with pork meat [15]. As the proportion of MUFA increased (in frankfurters in which pork fat was replaced by olive oil), the levels of total PUFA, n-6 and n-3 PUFA decreased slightly ($P<0.05$). The DHA concentration in frankfurters was close to the target level, ranging between 441 mg/100 g of product (S sample) and 374 mg/100g (OS sample), whereas total n-3 PUFA were at around 450-600 mg/100 g. Although dietary recommendations vary depending on different factors, these products can make a very important contribution to dietary intake as compared to non-fortified frankfurters [15], which generally present n-3 PUFA contents lower than 150 mg/100 g [4]. The PUFA/SFA ratio is one of the main parameters currently used to assess the nutritional quality of the lipid fraction of foods. Nutritional guidelines recommend a PUFA/SFA ratio above 0.4 [16]. PUFA/SFA ratios in C and S samples were similar ($P>0.05$), with values around 0.4 (Table 2), which is consistent with reports by other authors in conventional meat products [15]. Replacement of pork fat by olive oil increased this ratio ($P<0.05$) to 0.50, mainly as a result of reducing SFA (Table 2). The dietary recommendation for prevention of CVD is to reduce the n-6/n-3 ratio to less than 4. With the reformulation process used in this experiment, products were achieved with n-6/n-3 ratios close to 2 (Table 2), that is much lower than those of products formulated with pork meat alone, which were greater than 13 [15], and as expected, the olive oil had only a small effect on n-6/n-3 PUFA ratio (Table 2).

The addition of seaweed produced a minor change in the fatty acid profile [8] and this effect may be related to the low fat seaweed content (1.32 %) [2] and the amount added in frankfurter formulation (Table 1); as a result, the estimated contribution to the fat proportion in product was really low.

C. Sodium and potassium content

The addition of Sea Spaghetti accompanied by NaCl reduction produced changes in the mineral content of the frankfurters [8] presenting a significant decrease (>25 %) in the sodium content of the products (S and OS samples) (Table 3). As a result of substitution of potassium chloride for NaCl and addition of seaweed, S and OS samples contained higher concentrations ($P<0.05$) of K.

Products without seaweed and with normal salt contents (C and O samples) presented Na/K ratios over 3.6 (3.81 and 3.67 respectively) (Table 3), comparable to ratios reported for other similar products [17]. A high sodium chloride intake and diets with high Na/K ratios have been associated with the incidence of hypertension [18]. Although seaweeds are rich in sodium, they are doubly rich in potassium. Because of this and the replacement of 50 % NaCl by 50 % KCl, the resulting frankfurters (S and OS samples) presented Na/K ratios below 1.0 (0.62 and 0.71 respectively) (Table 3).

IV. CONCLUSION

Combination of fortification and enrichment strategies has been used to develop meat-based functional foods. By means of reformulation we were able to produce low-fat and low-sodium frankfurters enriched with MUFA and long chain n−3 PUFA and with a well-balanced n-6/n-3 ratio. Algal and olive (replacement animal fat) oils can be used to improve the lipid profile of frankfurters, supplying significant amounts of DHA through dietary intake. The addition of seaweed provides a means to develop, low-sodium frankfurters with better Na/K ratios and with various healthy compounds such as dietary fibre.

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Table 1. Formulation (%) of the different frankfurters enriched with DHA [x]

	C	S	O	OS
Meat	54.6	54.6	54.6	54.6
Pork backfat	9.55	9.55	3.89	3.89
Olive oil	0.00	0.00	5.00	5.00
Algal oil	1.14	1.14	1.14	1.14
Seaweed	0.00	5.50	0.00	5.50
NaCl	2.0	0.50	2.0	0.50
KCl	0.00	0.50	0.00	0.50
Water	31.2	26.7	30.9	26.3

[x] C, control frankfurter; S, Sea Spaguetti frankfurter; O, olive oil frankfurter; OS, olive oil + Sea Spaguetti frankfurter. DHA: Docosahexaenoic acid. The following were also added to all samples: 0.3 % STP, 0.012 % sodium nitrite, 0.53 % sodium caseinate, 0.6 % flavouring and 0.05% liquid smoke.

Table 2. Fatty acid composition (g/100 g of total fatty acids) and nutritionally significant ratios of frankfurters*.

	C	S	O	OS	SEM
∑SFA	37.72[a]	37.53[a]	28.14[b]	28.73[b]	0.15
∑MUFA	47.32[a]	47.71[a]	57.85[b]	57.59[b]	0.13
∑PUFA	14.96[a]	14.81[a]	14.01[b]	13.68[c]	0.03
∑n-6	9.10[a]	8.96[a]	8.43[b]	8.50[b]	0.03
∑n-3	4.87[ab]	5.00[b]	4.64[ac]	4.36[c]	0.08
PUFA/SFA	0.40[a]	0.39[a]	0.50[b]	0.48[c]	0.00
MUFA+PUFA/SFA	1.65[a]	1.67[a]	2.55[b]	2.48[c]	0.01
n-6/n-3	1.87[ab]	1.79[a]	1.81[a]	1.95[b]	0.03

*For sample denominations see Table 1. Means with different letters in the same file are significantly different ($P<0.05$). SEM: standard error of the mean.

Table 3. Sodium, potasium content (mg/100 g) and Na/K ratio of each frankfurter*.

	Sodium	Potasium	Na/K
C	950.0[a]	249.3[a]	3.81
S	558.1[b]	896.6[b]	0.62
O	927.1[a]	252.6[a]	3.67
OS	669.7[c]	937.5[c]	0.71
SEM	16.7	7.70	-

*For sample denominations see Table 1. Means with different letters in the same column are significantly different ($P<0.05$). SEM: standard error of the mean.

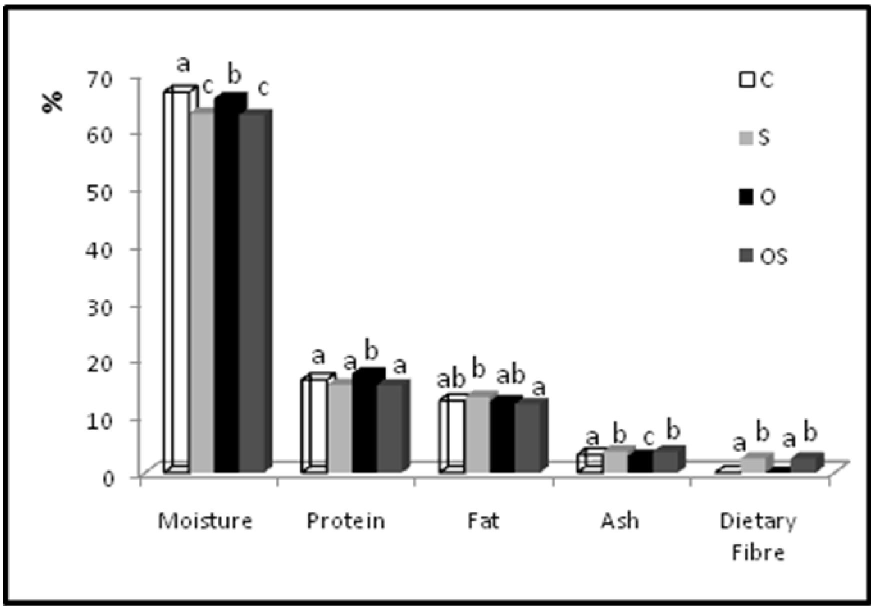

Figure 1. Proximate analysis (%) of frankfurters. C, control frankfurter; S, Sea Spaguetti frankfurter; O, olive oil frankfurter; OS, olive oil + Sea Spaguetti frankfurter. Means with different letters for the same component are significantly different ($P<0.05$).