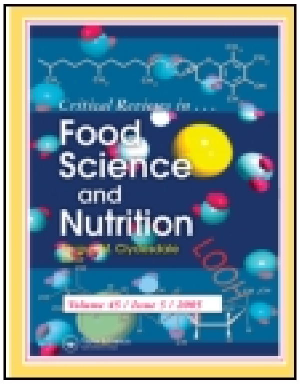

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Substitution of Saturated Fat in Processed Meat Products: A Review

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The food industry is increasingly directing its efforts to produce and commercialize functional foods where the reduction or even elimination of saturated fat is an important goal. This situation arises from the concern of many institutions and individuals worldwide on the growth of non-transmissible diseases, particularly cardiovascular ones. This article presents a revision of the most important research carried out on processed meat products production and looks at the topic from two principal points of view: the nutritional and technological function of fat and the way in which it is gradually being replaced in the above-mentioned products. Many ingredients have been used to substitute fat but while the results concerning the nutritional composition of the final products are generally acceptable, the sensory aspects are not completely solved. This review emphasizes the use of plastic fats because they allow the highest fat substitution levels during its process and consumption without affecting the product behavior.

Keywords fat, lard, backfat, fat replacer, functional food

INTRODUCTION

Fat is an undesirable component of meat for most consumers and is responsible for it being regarded as a not very healthy food (Arvanitoyannis and Van Houwelingen-Koukaliaroglou, 2005; Webb and OáNeill, 2008). Health authorities worldwide are encouraging people to decrease their consumption of saturated fatty acids (SFA), *trans* fatty acids, and cholesterol because of many studies which have pointed its direct relation with cardiovascular diseases. At the same time, campaigns encourage people to have balanced diets, take regular physical exercise, and in general assume healthy habits. Such advice has been incorporated into many norms and laws by a variety of organizations whose aim is to promote the health and well-being of people (Pan American Health Organization, 2007; OMS, 2004; FDA/CFSAN, 2004).

One consequence of this is that consumers are more aware of the fact that what they eat is linked directly to their health (Sampaio et al., 2004). This explains why more consumers are always looking to the nutritional information provided in a product and in many cases this information determines their decision whether to buy it or not.

Also, consumers are showing a preference for functional foods and this must be considered as an important challenge for the meat processing industry. Sausages are rich in SFA and cholesterol; both come from animal fat and have a limited place in a healthy diet. Therefore, there is a need to find fat replacers that will permit the development of meat products with a lower content of SFA, *trans* fatty acids, and cholesterol which at the same time will preserve the sensory qualities and shelf life of the products that guarantee their acceptance by consumers (Sampaio, et al., 2004; Muguerza et al., 2003; 2004).

The aim of this article is to present an overview of the back fat replacement in meat products to fulfil the textural functions that this fat provides to the final product. The fat origin of the products is emphasized because the calorie reduction per se is not the principal objective of the research being carried out. The revision looks at the nutritional and technological function of fat and the way in which it can be substituted in cooked meat products.

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NUTRITIONAL AND TECHNOLOGICAL FUNCTION OF FATS

The fats in the diet are composed of triglycerides, glycerol, and fatty acids, which are generally classified according to their chemical structure into saturated (SFA) and unsaturated (UFA), which in turn may be monounsaturated (MUFA) or polyunsaturated (PUFA). These fatty acids, depending on their proportions, define the physical properties and differentiate one fat from the others.

Pig hard fat is the most widely used fat in sausages because of the superior taste and textural characteristic that comes from its higher SFA content. Soft fats, on the other hand, contain a higher proportion of UFA that takes to both technological and sensory problems which persist in the product, where they affect its appearance, make difficult the cutting process, and lead to a greater tendency to oxidation (Maw et al., 2003). These aspects need to be kept in mind when designing or choosing a material of fatty origin to replace those generally present in the meat matrix.

The consumption of pig fat may increase the levels of SFA and cholesterol in the organism, where they are directly related with cardiovascular diseases (Bragagnolo and Rodriguez-Amaya, 2002; FDA/CFSAN, 2004; García-García and Totosaus, 2008; Muguerza et al., 2001; OMS, 2004; Pan American Health Organization, 2007; Williams, 2000; Wood et al., 2003). However, such characteristics are in sharp contrast to their technological qualities which make them indispensable in the manufacture of meat products. The technological and nutritional qualities of backfat are therefore inversely related (Hugo and Roodt, 2007), which means that great care has to be taken when designing a substitute for this material as both criteria must be fulfilled.

Nutritional Criteria for Good Quality Fats

The fat that is consumed as part of the diet performs various functions in the organism: it provides energy and essential fatty acids, maintains the body temperature constant, protects vital organs, facilitates the absorption of liposoluble vitamins (A, D, E, and K), and promotes the slow evacuation of the stomach, conferring the satiety sensation due to the high energetic density that it provides: 9 cal/g (Pinheiro and Penna, 2004).

Some studies have shown that low fat diets may increase triglyceride levels during fasting and after eating and reduce the protection capacity of High Density Lipoprotein (HDL) cholesterol (Williams, 2000). It is therefore necessary to adjust eating habits to ensure the ingestion of adequate proportions of fatty acids.

The consumption of recommended fat levels in the diet (total fat should be less than 30% and SFA less than 10% of daily total energy intake) will enable the organism to fulfil its functions, while diminishing the risk of cardiovascular diseases (Williams, 2000; Wood et al., 2003). In addition, MUFA have a neutral/favorable effect on cardiovascular diseases (Warnants et al., 1998; Williams, 2000).

The main parameters studied to determine the nutritional quality of the lipid fraction of the diet are: the SFA/PUFA ratio and *n*-3/*n*-6 PUFA (Pelser et al., 2007; Ansorena and Astiasarán, 2004), as well as the Total Fatty Acids (TFA) and cholesterol content.

PUFA/SFA Ratio

Fatty acids have different effects according to the concentrations of lipids and lipoproteins in blood plasma. SFA of 12–16 carbons long tend to raise low density lipoprotein (LDL) and total cholesterol levels, the strongest effect has been attributed to lauric (C12:0), myristic (C14:0), and palmitic (C16:0) acids while stearic acid (18:0) has no effect on cholesterol (Risérus et al., 2009; Hu et al., 2001; Valsta et al., 2005; Williams, 2000).

The main health benefits of PUFA intake are associated with the consumption of *n-3* fatty acids. Epidemiological studies and clinical assays have demonstrated that *n-3* PUFAs reduce the incidence of cardiovascular diseases (Kris-Etherton et al., 2002; Wang et al., 2006; Webb and OáNeill, 2008; Williams, 2000).

To improve health it is recommended to eat foods rich in *n*-3 PUFA, maintaining the PUFA/SFA ratio greater than 0.4 (Ansorena and Astiasarán, 2004; Hugo and Roodt, 2007; Pelser et al., 2007; Özvural and Vural, 2008; Webb and OáNeill, 2008; Wood et al., 2003). This may be achieved by replacing SFA in the diet by PUFA or MUFA, where PUFA could be more effective in the cholesterol levels reduction but their lipoperoxidation products may have potentially adverse effects (Williams, 2000).

Meat naturally has 0.1 PUFA/SFA ratio which implies an imbalance in the fatty acids intake (Webb and Oá;Neill, 2008; Wood et al., 2003) while backfat has a value greater than of 0.4 (Gläser et al., 2004; Warnants et al., 1998; Ospina et al., 2010). This means that in the design of a fat replacer attention should be paid to the SFA content in order to improve the PUFA/SFA ratio in the final product.

PUFA n-6/n-3 Ratio

The *n-3* and *n-6* fatty acids cannot be synthesized by humans and therefore they are considered essential fatty acids. The *n-6* fatty acids can be elongated as far as arachidonic acid (C20:4 n-6) which acts as a precursor in the eicosanoids formation. The role of *n-3* PUFA is important because it inhibits the eicosanoids biosynthesis and reduces inflammation; also, it increases the levels of HDL cholesterol and reduces LDL cholesterol levels (Johnston, 2009; Osborn and Akoh, 2002; Simopoulos, 2000; 2002). This explains why the *n-6/n-3* ratio has been studied as a risk factor in cardiovascular diseases especially via pro-thrombotic and pro-inflammatory pathways that could lead to heart attacks (Fernández-Ginés et al., 2005; Williams, 2000; Wood et al., 2003).

The principal source of *n-6* in the diet is linoleic acid (C18:2) which is found at high concentrations in pork unlike in other meat species (Wood et al., 2003). The sources of *n*-3 PUFA are α-linolenic acid (C18:3), eicosapentanoic acid (EPA, C20:5), and docosahexanoic acid (DHA, C22:6). However, it has been demonstrated that the increased consumption of *n-3* from C18:3 has no beneficial effect on health (Wang et al., 2006).

The *n-6/n-3* western diets ratio is around 15–20 and the recommendation is to eat more foods rich in *n-3* in order to keep the *n-6/n-3* ratio below 4 (Ansorena and Astiasarán, 2004; Hugo and Roodt, 2007; Pelser et al., 2007; Simopoulos, 2000; Webb and Oá;Neill, 2008; Wood et al., 2003).

This *n-6/n-3* ratio in the meat and fat of animals can be modified by altering their feed if the subsequent meat sensory qualities are not important (Moghadasian, 2008; Ngapo and Gariépy, 2008; Valencia et al., 2007; Wood et al., 2003). However, it is possible to design pig fat substitutes that do not affect the sensory characteristics of the final meat products and improve their *n-6/n-3* ratio.

To summarize, it is not a question of improving the PUFA/SFA ratio by simply adding more PUFA instead of SFA; also, it is important to consider the ratio within this group of *n-6* and *n-3* PUFAs.

Trans Fatty Acids

The *trans* fatty acids are some of the isomers that may be formed in the UFA. Despite being unsaturated, *trans* fatty acids behave as SFA due to their spatial conformation, because they form lineal chains around the double bond which may be packed into confined spaces and therefore have similar effects as saturated fatty acids on the organism (Semma, 2002).

Although SFA are mainly responsible for increasing the level of LDL in the diet, *trans* fatty acids and dietetic cholesterol make their own significant contribution (FDA/CFSAN, 2004; Williams, 2000). The direct relation between the consumption of *trans* fatty acids and the risk of cardiovascular diseases may be the result of several mechanisms: increased levels of seric LDL cholesterol and decreased levels of HDL cholesterol, increased plasma levels of triglycerides, inhibition of the Δ6-desaturase enzyme which participates in the metabolism of essential fatty acids, and prostaglandins that may lead to thrombogenesis (Tanasescu et al., 2004; Hu et al., 1999; 2001; Risérus et al., 2009; Williams, 2000).

Besides their negative effects on cardiovascular health, SFA have another harmful effect like inhibiting the essential fatty acids conversion which have important functions in the nervous system development and the correct sight operation since they use the same enzymes to be metabolized (IFST, 2007).

Many laws have attempted to make mandatory mentioning the content of this fatty acid type on labels. It is for this reason that design of any food should consider their inclusion in the formula where they are important not only for their technological function but also for their nutritional contribution.

Cholesterol

Cholesterol is an essential component of animal cell membranes and a precursor of biologically active compounds such as bile salts, important hormones, and vitamin D3 (Morgado, 2008). Although cholesterol is frequently related to risk factors associated with developing cardiovascular diseases, it would be more correct to speak of the association between cholesterol and the HDL and LDL.

The body's cholesterol homeostasis depends on the precise regulation of the cholesterogenesis processes, diet's cholesterol absorption and excretion. Any imbalance through these processes may turn into several health problems like high cholesterol concentrations in plasma, its accumulation in tissues and increased risk of CV diseases (Calpe-Berdiel et al., 2009). In addition, there is a direct relationship between high plasmatic cholesterol levels, especially LDL types, and the risk of cardiovascular diseases (Calpe-Berdiel et al., 2009). LDL reduction seems to stabilize the plaque burden and therefore reduces future cardiovascular events. When the HDL cholesterol is increased, plaque burden could be decreased, intensifying the effectiveness in primary prevention and in advanced atheroma progression (Sirtori and Fumagalli, 2006).

Meat and meat products are important cholesterol sources, they usually provide between 30 and 120 mg of cholesterol per 100 g of food (Valsta et al., 2005). Mixtures of vegetal oils can be designed to ensure the absence of cholesterol in fat replacers and limiting its presence in meat products only to that contributed by the meat itself. This empowers the manufacturer to concentrate on other nutritional fat quality factors when planning a pig fat substitute.

Technological Criteria of Good Quality Fat

Fat is in meat supply animals like subcutaneous deposits as intermuscular and intramuscular forms. Each of these fatty deposits has a particular role in processed meat products. That is why intramuscular fat is particularly desired in the production of ham, intermuscular fat in spreadable products, and subcutaneous fats in the majority of emulsified and mixed meat products.

Backfat is a hard fat used in the manufacturing of meat products and technologically it is preferred to bovine and poultry fats. SFA in pig are present in both meat and lard, the exact proportion varying with the fat present in the feed provided to the animals (Eder et al., 2001; Hugo and Roodt, 2007; Nuernberg et al., 2005; Pascual et al., 2006; Seman, 2008).

Backfat gives textural attributes to meat products such as hardness, gumminess, juiciness, and chewiness, as a result of its physical characteristics that depend on temperature and fatty acid composition (Muguerza et al., 2001; Hsu and Yu, 2002; Fernández-Ginés et al., 2005; Hugo and Roodt, 2007; Wood et al., 2003). Those technological quality attributes are defined by aspects such as: the percentage of extractible fat, firmness, consistency, color, iodine index, C18:2 content, C18:0/C18:2 ratio, the double bond index, fatty acid content, fusion behavior, solid fat content (SFC), free fatty acid content, oxidative stability, peroxide index, saponification index, crystallization time, among other factors (Wood et al., 2003; Gläser et al., 2004; Hugo and Roodt, 2007; Seaman, 2008).

The aspects that predict the technological attributes of fat, both physical and chemical, always depending on temperature, are shown in Figure 1. It can be seen that three of the most important physical characteristics are crystallization time, melting point, and slip point may lie in the SFC as one of its points, regardless of the method used to measure it. For this reason, the analysis of this variable which determines the quantity of fat in solid and liquid state at a given temperature is more complete. Other chemical indexes are important from the fat lipid oxidation point of view and the consequences of such oxidation in the elaboration of processed meat products .

Physical Characteristics

Good quality backfat is usually defined as the one which is white and firm, although it is also important to consider its melting behavior.

Chemically, the instauration level of backfat may be sufficient for predicting the firmness behavior of backfats, but not all the aspects are related to the melting point because it also depends on the MUFA and PUFA content. In the same way the consistency of the fat could be predicted by variables such the SFA content particularly C18:0, C18:2, and the ratio between them, the MUFA/SFA ratio and the iodine index (Gläser et al., 2004).

The melting point and pig fat consistency are related to the C18:0 content. Palmytic acid may influence the consistency more at low temperatures when the slip point is used to measure it. When the C18:2 content is greater than 15%, the fat firmness and melting point are determined by this fatty acid and the C16:0 content (Hugo and Roodt, 2007).

Gläser et al. (2004) maintained that although the firmness of backfat depends on the fatty acid make-up only 30% of the variation can be explained by this variable. There are other factors such as the fat, water, and collagen contents, all of which are related and the proportion of surface fat which shows the best

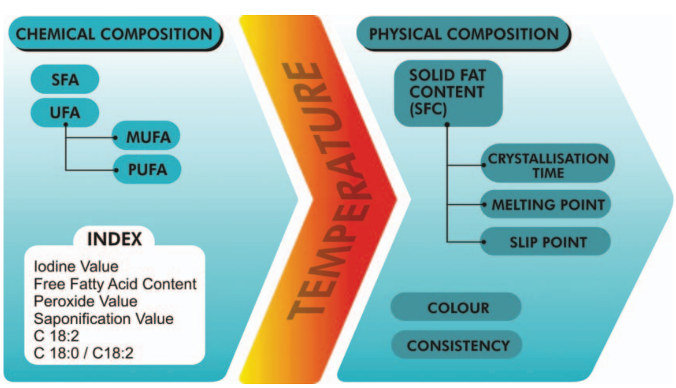

Figure 1 Physical and chemical parameters used as quality criteria in backfat. (color figure available online.)

correlation. From these observations, it seems that the quantity of surface fat and its thickness are more important for the firmness than the composition of the backfat.

Consistency might also be related to the SFC. For example, Davenel et al. (1999) suggested that a SFC20 of less than 15% represents a soft fat while a SFC20 of more than 18% represents a hard pig adipose tissue. The SFC is more related with the SFA content than with other fatty acids present in backfat (Davenel et al., 1999; Gläser et al., 2004). Furthermore, the SFA content is directly related with the melting point of fat (Wood et al., 2008). When fat cells have a higher melting point they are in a solid state at room temperature and are more white in color than fats of lower melting point (Wood et al., 2003) which is another characteristic of a good quality fat.

However, color is not the most critical variable when it comes to thinking of pork fat replacers and several studies have pointed out that the use of vegetal oils instead of backfat does not produce significant changes in the color of finished products when assessed by a sensory panel (Muguerza et al., 2001; Pelser et al., 2007).

Lard consistency is then the most interesting physical variable because it is the attribute that will finally gives texture characteristics to the finished product. The relation of other physical variations, especially SFC for predicting how consistency will behave at different temperatures is important when designing a fat replacer; it is also important to consider that the chemical composition will modify the physical lard behavior.

Chemical Composition

The chemical characteristics evaluated in the lard are the extractible fat percentage and fatty acid profile with particular reference to total C18:2, the C18:0/C18:2 ratio and the double bond index (Hugo and Roodt, 2007). Oxidation is another important quality index associated with the chemical composition since it affects fat color and taste with time. Some of the data studied by other authors and revised by Hugo and Roodt (2007) are shown in Table 1, which includes several indexes based on the chemical composition and associated with the technological criteria defining good quality backfat.

When a comparison is made between the values that define a good nutritional quality backfat (PUFA/SFA > 0.4 and PUFA $n\text{-}6/n3 < 4$) and the good technological quality indexes (Table 1) it can be seen that it is not possible to maintain the relations suggested from a nutritional point of view (PUFA/SFA $= 0.366$ and PUFA $n\text{-}6/n3 = 4$). As more fat is added to the meat product, the nutritional quality decreases and the ratio of the fatty acids gets worse.

Considering the large number of criteria necessary to define lard quality, in order to get a good backfat substitute, the most representative physical characteristics should be preserved while the chemical characteristics should be modified to reach the nutritional criteria identified as good quality fat indexes.

SUBSTITUTING FAT IN MEAT PRODUCTS

Meat products are ripe candidates for being modified and turned in healthy products through the addition of ingredients considered beneficial for health or through the elimination or reduction of those components considered harmful (Fernández-Ginés et al., 2005). Among these components fat must be included as one of the factors that could be used to adjust the nutritional characteristics of the product.

The substitution of fat has been studied for many years and has its own terminology. For example, Akoh (1998) coined the term "fat replacers" to denote the ingredients or additives used to diminish the fat content in foods. These are ingredients which structurally may be considered fats, proteins, or carbohydrates, that is, any raw material used to replace fat in the formulation. Within the group of "fat replacers" there are two sub-groups: "fat mimetics" and "fat substitutes."

Fat Mimetics

These are substances that mimic the physical and organoleptic triglycerides characteristics but cannot replace the fat on a 1:1 basis. Basically these types of ingredients are carbohydrates and proteins that require hydration to fulfil their function as fat replacers. However, they have their drawbacks: for example, they undergo caramelization and denaturalization when they are submitted to high temperatures; they have soluble but not lipidic flavors so the taste is less and generally require additional preparation processes. Their main advantage is that Fat Mimetics reduce food caloric content (Akoh, 1998).

Partial substitution of backfat with Fat Mimetics has been developed in order to reduce the negative effect of the high fat content in meat products. In several studies where fat has been partially replaced by fat mimetics the ingredients used were water, proteins, and polysaccharides like maltodextrins, gums, carragenins, fibers, inulin, starch, flours, bran, and even tubers (Andrès et al., 2006; Cengiz and Gokoglu, 2007; Cierach et al., 2009; Crehan et al., 2000; García et al., 2002, 2006; García-García and Totosaus, 2008; Fernández-Ginés et al., 2005; Mendoza et al., 2001; Nowak et al., 2007; Piñero et al., 2008; Salazar et al., 2009; Sampaio et al., 2004; Shon and Chin, 2008; Tan et al., 2007).

Table 1 Technological criteria defining a good quality lard (adapted from Hugo and Roodt, 2007)

Variable	% min	% max
Composition		
Extractable fat	84	90
SFA	41	—
UFA	—	59
MUFA	—	57
PUFA	—	15
C18:0	12	—
C18:2	12	15
C18:0/C18:2	1.2	—
Oxidation		
PUFA	—	23
dienoic fatty acid	—	10
trienoic fatty acid	—	1.0
tetraenoic fatty acid	—	0.5
pentaenoic +hexaenoic fatty acid	—	1.0
Double bonds index	—	80

Fat Substitutes

These are macromolecules that physically and chemically resemble triglycerides and so they can be expected to be used as fat substitutes in a 1:1 proportion. Generally they are elaborated from conventional fatty acid bases that are physically and chemically altered (Akoh, 1998). Animal fat substitutes made from vegetal oils have gained much attention in the processed meat industry. Such fat substitutes can be classified into two groups: liquids and plastics (Tan et al., 2006).

Liquid fats are basically represented by vegetal oils and have been seen to have a positive impact on nutritional aspects as represented by reduced cholesterol content and improved PUFA/SFA and *n-6/n*–3 ratios. Sunflower, maize, peanut, tea seed, coconut, palm, soy, and olive oils as well as fish oil have been evaluated *(*Hsu and Yu, 2002; Fernández-Ginés et al., 2005; López-López et al., 2009; Moghadasian, 2008; Muguerza et al., 2001; 2002; 2003; 2004; Severini et al., 2003; Yildiz-Turp and Serdaroğlu, 2008).

Having in mind the proportions mentioned above, the use of vegetal oils can be compared with the use of soft fats which are characterized by their poor appearance, difficulty to cut, and greater tendency to oxidize than hard fats (Maw et al., 2003). This tendency to oxidization in the products containing vegetal oils instead of lard is due to the greater unsaturated fatty acid content, that is why it is vital to define the shelf life that results from increased rancidity and decoloration (Fernández-Ginés et al., 2005; Hugo and Roodt, 2007; Webb and OáNeill, 2008).

Plastic fats are obtained by chemically and enzymatically altering some oils; they appear to be solid and are resistant to light forces but when these forces pass a certain value plastic fats flow like liquids (Osborn and Akoh, 2002). Partial hydrogenation and interesterification are used to modify oils in an attempt to simulate the consistency and melting point of animal fat. Interesterification is a healthy alternative because it does not cause saturation of the fatty acids and does not form *trans* fatty acids (Özvural and Vural, 2008; Vural et al., 2004). Animal fats have been replaced with a variety of vegetal oils including palm, cotton, olive, hazelnut, and their mixtures (Özvural and Vural, 2008; Vural et al., 2004).

The most recent studies into the replacement of animal fats in meat products are depicted in Table 2. The studies involving plastic fats are remarkable instead of the traditional use of vegetal oils and their pre-emulsified forms.

Table 2 Fat substitution in processed meat products

Authors	Product	Add Fat (%)	Substitution (%)	Substitute	Cooking loss	Consistency	Sensory Prop. (acceptability): Appearance	Sensory Prop. (acceptability): Texture	Sensory Prop. (acceptability): Flavor: Taste	Sensory Prop. (acceptability): Flavor: Odour	Sensory Prop. (acceptability): Color	Sensory Prop. (acceptability): Overall	Color: L*	Color: a*	Color: b*	TPA: Hardness	TPA: Cohesiveness	TPA: Gumminess	TPA: Springiness	TPA: Chewiness	TBA Value	Author Conclusion
Choi et al. (2010)	Frankfurtrers	30	50*	OO + SC (PE) + RBF	<			≈	≈	≈	<	≈									>	Yes
			50*	GSO + SC (PE) + RBF	<			≈	≈	≈	<	≈									>	Yes
			50*	CO + SC (PE) + RBF	<			≈	≈	≈	<	≈									>	Yes
			50*	KO + SC (PE) + RBF	<			≈	≈	≈	<	≈									>	Yes
			50*	SO + SC (PE) + RBF	<			≈	≈	≈	<	<									>	No
Choi et al. (2009)	Meat batter emulsified	30	50*	OO + SC (PE) + RBF	<								<	<	>	>	>	>	<	<		Yes
			50*	GSO + SC (PE) + RBF	<								<	<	>	>	>	>	<	<		Yes
			50*	CO + SC (PE) + RBF	<								<	<	>	>	>	>	<	<		Yes
			50*	KO + SC (PE) + RBF	<								<	<	>	>	>	>	<	<		Yes
			50*	SO + SC (PE) + RBF	<								<	<	>	>	>	>	<	<		Yes
Martín et al. (2008)	Pork Liver Paté	30	50	OO + SC (PE)		<															≈	No
		30	50	CLA + SC (PE)		<															≈	No
		30	50	OO50% + CLA50% + SC (PE)		<															≈	No
Özvural and Vural (2008)	Frankfurters	10	100	PO			≈	<	<		≈	<	>	≈	>	<	≈	<	≈	<		Yes
			100	PS			<	<	<		<	<	>	≈	>	≈	≈	<	≈	<		Yes
			100	CSO			≈	≈	<		≈	≈	>	>	>	<	≈	<	≈	<		Yes
			100	HO			≈	<	≈		≈	≈	>	≈	>	<	<	<	≈	<		Yes
			100	33.3%PO + 33.3%PS + 33.3%HO			≈	≈	≈		≈	≈	≈	<	>	<	≈	<	≈	<		Yes
			100	33.3%PO + 33.3%PS + 33.3%CSO			≈	≈	<		≈	<	>	≈	>	<	≈	<	≈	<		Yes
			100	16.6%PO + 16.6%PS + 66.6%HO			≈	≈	≈		≈	≈	>	<	>	<	<	<	≈	<		Yes
			100	16.6%PO + 16.6%PS + 66.6%CSO			≈	<	<		<	<	>	<	>	<	<	<	≈	<		Yes
			100	8.3%PO + 8.3%PS + 83.4%HO			≈	<	≈		≈	≈	>	≈	>	<	<	<	≈	<		Yes
			100	8.3%PO + 8.3%PS + 83.4%CSO			≈	≈	<		≈	<	>	<	>	<	<	<	≈	<		Yes
Yildiz-Turp and Serdaroğlu (2008)	Turkish fermented sausage (Sucuk)	20	15	HO + WP (PE)	≈	≈	≈	≈	≈	≈	≈	>	≈	≈	≈						≈	Yes
			30		<	≈	≈	<	≈	≈	≈	≈	≈	>	≈						≈	Yes
			50		<	<	≈	<	<	<	≈	≈	≈	>	≈						≈	No
Valencia et al. (2007)	Chorizo Pamplona	25	15	Algae *Schizochytrium* sp. Oil			≈		≈	≈											>	Yes
			25				≈		≠	≈											<	No
Pelser et al. (2007)	Dutch style fermented sausage	30	10	FSO + SP (PE)																	>	No
			15	FSO + SP (PE)																	>	No
			20	FSO + SP (PE)																	>	No
			10	KO + SP (PE)																	≈	No
			15	KO + SP (PE)																	≈	No
			20	KO + SP (PE)																	≈	No
			20	FSO + SP (PE)									≈	≈	>	<					>	No
			20	FSO + SP (SC)									≈	≈	>	<					>	No
			15	Encapsulated FSO									≈	≈	≈	<					≈	Yes
			15	Encapsulated FO									≈	≈	≈	<					>	No
Tan et al. (2006)	Chicken Frankfurters	20	50	PS	≈			<	≈	≈		≈				>	>		≈	>		No
			100	PS	≈			<	<	≈		<				>	>		≈	>		No
			100	PS50% + PO50%	≈			<	<	≈		≈				>	>		≈	>		No
			100	PO	≈			≈	<	≈		≈				≈	≈		≈	≈		Yes
			50	PO	≈			≈	≈	≈		≈				≈	≈		≈	≈		Yes
			66.6	PS 50% + PO50%	>			<	≈	≈		≈				>	≈		≈	≈		No
			33.3	PS 50% + PO50%	≈			≈	≈	≈		≈				≈	≈		≈	≈		Yes
			83	PS80% + PO20%	≈			<	≈	≈		<				>	>		≈	>		No
			83	PS20% + PO80%	>			≈	≈	≈		≈				>	>		≈	≈		Yes

(Continued on next page)

Table 2 Fat substitution in processed meat products (*Continued*)

							Sensory Prop. (acceptability)						Color			TPA						
Authors	Product	Add Fat (%)	Substitution (%)	Substitute	Cooking loss	Consistency	Appearance	Texture	Flavor: Taste	Flavor: Odour	Color	Overall	L*	a*	b*	Hardness	Cohesiveness	Gumminess	Springiness	Chewiness	TBA Value	Author Conclusion
Valencia et al. (2006)	Chorizo Pamplona	25	100	Deodorized FO + SP (PE)				≈	<	≈	≈	≈	<	>	>						<	Yes
Ansorena and Astiasarán (2004)	Chorizo Pamplona	25	25	LO + SP (PE)			≈			≈											>	Yes
			25	LO + SP + BHA + BHT (PE)			≈			≈											≈	Yes
Vural et al. (2004)	Frankfurters	10	60	Intersterfied PO + SBF		≈	≈	≈	≈	≈	≈											Yes
			100	Intersterfied PO + SBF		≈	≈	≈	≈	≈	≈											Yes
			60	Intersterfied CSO + SBF		≈	≈	≈	≈	≈	≈											Yes
			100	Intersterfied CSO + SBF		≈	≈	≈	≈	≈	≈											Yes
			60	Intersterfied OO + SBF		≈	≈	≈	≈	≈	≈											Yes
			100	Intersterfied OO + SBF		≈	≈	≈	≈	≈	≈											Yes
Severini et al. (2003)	Salami	15	33.3	OO + SC (PE)				≈		≈	≈	≈	≈	≈	≈	<					>	Yes
			50					<		<	<	<	≈	≈	≈	<					>	No
			66.6					<		<	<	<	≈	≈	≈	<					>	No
Muguerza et al. (2003)	Chorizo Pamplona	25	15	SO + SP (PE)				≈	≈		≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	<	Yes
			20					<	≈		≈	<	≈	≈	≈	≈	>	>	≈	>	<	Yes
			25					≈	≈		≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	<	Yes
Hsu & Yu (2002)	Low Fat Kung-Wans	25	0**	BF	≈			≈	≈	≈	≈	≈	≈	≈	≈	>	≈	>	≈	>	>	N/A
		25	100**	W	>			≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	N/A
		25	100**	CNO	≈			≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	>	≈	>	>	Yes
		25	100**	PO	≈			≈	≈	≈	≈	≈	≈	≈	≈	>	≈	≈	≈	≈	>	Yes
		25	100**	SO	≈			≈	≈	<	≈	≈	>	≈	≈	>	≈	>	≈	>	>	Yes
		25	100**	SFO	≈			≈	≈	≈	≈	≈	≈	≈	≈	>	≈	>	≈	≈	>	No
		25	100**	CO	≈			≈	≈	≈	≈	≈	≈	≈	≈	>	≈	>	≈	>	>	No
		25	100**	PNO	≈			≈	<	<	≈	<	≈	≈	>	>	>	>	≈	>	>	No
		25	100**	TO	≈			≈	<	<	≈	<	>	≈	>	>	≈	>	≈	>	>	No
		25	100**	OO	≈			≈	≈	≈	≈	≈	>	≈	≈	>	≈	>	≈	>	>	Yes
		25	100**	Hydrogenated CNO	≈			≈	≈	≈	≈	≈	≈	≈	≈	>	≈	>	≈	>	>	No
		25	100**	Hydrogenated PO	≈			≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	≈	>	No
		25	100**	Hydrogenated SO	≈			≈	≈	≈	≈	≈	≈	≈	≈	>	≈	>	≈	>	>	Yes
Muguerza et al. (2001)	Chorizo Pamplona	25	10	OO + SP (PE)				≈	≈	≈	≈	≈	≈	≈	<							Yes
			15					≈	≈	≈	≈	≈	<	≈	≈							Yes
			20					≈	≈	≈	≈	≈	>	<	≈	<	>	<	<	<		Yes
			25					<	≈	≈	<	≈	<	≈	<	<	<	<	<	<		Yes
			30					<	≈	≈	<	≈	≈	≈	≈	<	<	<	≈	<		No

* The total fat content is also reduced to 20%

** The total fat content is also reduced to 10%

≈ without statistical significance ($p > 0.05$), except Severini et al. (2008) with $p > 0.08$; < less than control, > higher than control

OO: Olive Oil, GSO: Grape Seed Oil, CO: Corn Oil, KO: Canola Oil, SO: Soybean Oil, PO: Palm Oil, PS: Palm Stearin, CSO: Cottonseed Oil, HO: Hazelnut Oil, FSO: Flaxseed Oil, FO: Fish Oil, BF: Back Fat, W: Water, CNO: Coconut Oil, SFO: Sunflower Oil, PNO: Peanut Oil, TO: Tea Seed Oil, LO: Linseed Oil, CLA: Conjugated Linoleic Acid, PE: Pre-emulsified, SC: Sodium Caseinate, SP: Soybean Protein, WP: Whey Protein, RBF: Rice Bran Fiber, SBF: Sugarbeet Fiber

Studies where pig fat was substituted by interesterified vegetal oils, 100% substitution has been reached in products where the fat content does not exceed 10% of the formula with good sensory results (Özvural and Vural, 2008; Vural et al., 2004). However, some products have a greater percentage of fat which means that solutions have to be found to the problem this represents.

Another alternative included in Table 2 is the use of vegetal or animal oils as individual substitute in products with an added fat content lower than 10%, for which good organoleptic results have been obtained (Hsu and Yu, 2002; Özvural and Vural, 2008; Pelser et al. 2007; Tan et al. 2006; Valencia et al., 2007). However, as the level of fat increases in the formula so the level of substitution falls; for example, substitutions of more than 25% of the fat in products containing more than 20% added fat have not been successful.

The use of intermediate processes such as pre-emulsions using different types of protein represents an improved way of incorporating oil in meat matrices, with this higher levels of fat substitution have been obtained than those with the direct use of oils (Ansorena and Astiasarán, 2004; Choi et al., 2010; 2009; Martin et al., 2008; Muguerza et al., 2001; 2003; Pelser et al., 2007; Severini et al., 2003; Valencia et al., 2006; Yildiz-Turp and Serdaroğlu, 2008). However, no substitutions above 25% have been possible when fat exceeds 25%. Moreover, from an industrial point of view this type of solution is not interesting because it would affect productivity especially in cooked products cases.

The results obtained in measuring different response variables (Table 2) indicate that it is the sensory characteristics that finally define the fat substitution success, although instrumental color measures and textural and lipid oxidation analysis are also objective evaluations to get closer to the organoleptic profile and provides a more complete evaluation to compare the results from different studies (Ngapo and Gariépy, 2008), even though it is necessary to establish a hierarchy or an evaluations system to conclude.

CONCLUSIONS

By following the nutritional indexes suggested throughout this revision, meat products can be considered as neutral character food that not reduces or increases the risk of cardiovascular diseases. However, fat is not the only source of fatty acids in processed meat products and meat itself may be a contributor to the deterioration of the suggested indices. Moreover, meat products are not the only components of the human diet and other sources of fat should be borne in mind to maintain the balance suggested. Finally, the risk of cardiovascular diseases is associated with eating habits in general, lifestyle, and even has a genetic component. The meat industry's responsibility should be at least to offer products that do not increase the risk of appearance of non-transmissible diseases.

Loads of fat replacer have been evaluated to reduce the fat added to meat products; however, the ideal one has not yet been identified. The use of plastic fats as backfat substitutes permits high levels of substitution, sensory attributes to be maintained, and the nutritional characteristics of processed meat products to be improved. The use of mixtures of chemically modified vegetal oils should be explored for products with a high level of added fat.

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