PJN
ISSN 1680-5194

PAKISTAN JOURNAL OF NUTRITION

ANSInet
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan
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Pakistan Journal of Nutrition 2 (3): 196-203, 2003

Fat Replacers in Meat Products

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Abstract: There is a great interest regarding demand for foods with health enhancing properties as low-fat meat products due to the human health and nutrition correlation. Various aspects of interest relating to product design and fat reducing strategy has been reported. These aspects concerning nutritional, sensory, technological, safety, appreciation, legal and cost procedures are important to a improved new product design. Due to their different texture properties, processing conditions and different quality evaluations used in the reformulated meat derivatives, the feasibility of low-fat meat products manufacturing has been investigated. In previous review paper, various factors such as consumer acceptability, technological, emerging strategies for the modification of meat fat level, fatty acid (FA) composition, and non-meat ingredients or fat-replacers for the production were monitored for low-fat meat products and fat reduction concept.

Key words: Meat, fat reduction, fat replacers

Introduction*

Meat is a major component of the diet in developed countries. One of the most important commodity of total expenditure regarding food sector in the most European countries and USA, is meat products. It accounts for about 30% of expenditure in Italy, Spain and Ireland, 30% in Turkey, 25% in the UK, The Netherlands and Greece and 35% in Denmark, France and Belgium (Anonymous, 2002; Tuley, 1996).

Due to the meat and meat products lead to certain diseases, the meat industry has been worst hit by adverse publicity. The role of fat as one of the main causes of cardiovascular disease has been well documented (Rossum *et al*., 2000). Fat , trans fatty acids (FAs), cholesterol and saturated FAs of meat products have also been associated with obesity and cancers (especially colon, prostate and breast) in developing countries (Slattery *et al*., 1999; Grundy, 1994). Extensive researches have been performed on fat replacement to improve quality of many products (Jimenez Colmenero, 2000; Allen *et al*., 1999; Lucca and Tepper, 1994).

Fat content has a basic effect on various physico-chemical and sensory characteristics as flavour, moutfeel, juiciness, texture, handling, bite, heat transfer etc.) (Fig. 1) (Pearson and Gillett, 1999) and it can not be modified and/or reduced with improper less fat or another type of fat. The food industry has responded to consumer demand by offering an ever-increasing variety of low-fat meat choices. Many good-tasting, low-fat meats are available today thanks to the growing use of one or more low-calorie fat replacers.

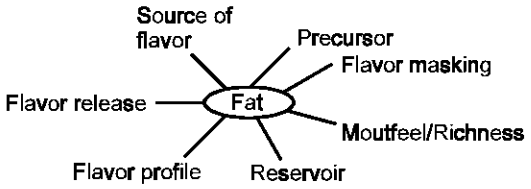

Fig. 1: Various physico-chemical and sensory characteristics on fat content (Pearson and Gillett, 1999)

The aspects on low-fat meat concept: Reducing dietary fat is a major dietary goal for many consumers. There are various aspects of interest relating to product design and fat reducing strategy (Fig. 2). These specific considerations regarding nutritional, sensory, technological, safety, appreciation, legal and cost procedures are important to a improved product design.

Sensory factors: Low-fat meat products which are not acceptable in terms of palatability or appearance will not sell regardless of the health characteristics attributed to them due to the consumption of processed meat is closely related to public taste. Acceptable flavour, texture and other sensory characteristics in reformulated meat products is important. However fat has been shown to improve palatability by increasing tenderness and juiciness (Jimenez Colmenero, 2000; Byers *et al*., 1993).

*One part of this research was presented at 2nd World Engineering Congress July 22-25, Sarawak, Malaysia (2002)

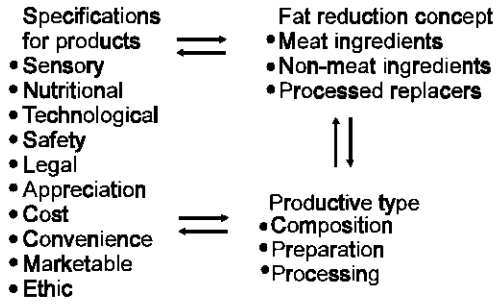

Fig. 2: Low-fat meat assessment and major factors affecting the low-fat meat products. (Jimenez Colmenero, 2000)

Some studies indicated that, there is no direct relationship between these two parameters and consumers have been preferred products with intermediate fat content.

The choice of fat level of meat products has been established as the benchmark for reformulated meat products according to sensory taste panelists. Flavour is particular problem for low-fat meat products owing to decreases when fat is reduced. Besides, an increased moisture/fat ratio may mean that spices level and other flavourings has to be modified (Jimenez Colmenero, 2000).

Nutritional factors: In food selection, nutrition is a crucial factor (Jimenez Colmenero, 2000; Bruhn *et al*., 1992). Moreover ,supplying much of the energy that the body requires, animal fat is a source of liposoluble vitamins (A, D, E, K), essential fatty acids and precursors of prostaglandins that regulate a number of physiological functions. Meat in the proper proportions is an essential component of any balanced diet and therefore fat reduction degree is more important for sensory and technological factors and also for preventing of nutritional properties in food industry. The percentage of calories from fat is an other factor for product evaluating. Even in meat products which are 94% fat free, fat may account for over 50% of calorie content. To access the 30% calorie limit, meat products must be made leaner such as 98% fat-free or the calories from fat diluted out with proteins or carbohydrates to obtain a more balanced protein/fat/ carbohydrate profile (Shand *et al*., 1990). Lipids gives a satiety feeling due to their high energy value. Lipid digestion is slow and it delays the perception of a need to consume more food but reformulated meat products do not gives a feeling of satiety, the amount of food intake tolerate this perception (Jimenez Colmenero, 2000).

Other factors: Technological, safety, appreciation, legal and cost procedures are other essential considerations to a improved product design.

Low-fat meat products need to be handled safely due to their perishable characteristics. Thermal treatment has been regulated to improve palatability. The microbiological controls are also crucial for shelf-life of reformulated meats. Technological applications such as temperature fluctuations, pressure, vacuum packaging etc. effect the product quality. For instance, purge loss (in vacuum packaging) lead to unpleasant appearance and lead to induce microbial growth with consequent loss of shelf-life. Appreciation including preference, usefulness, profit, social aspects etc. is also important for product assessment. Recent or emerging strategies to modify fat level, fatty acid composition, cholesterol, transgenic technology (with some non-meat ingredients from genetically engineered vegetables) can give some problems from the standpoint of consumer acceptance. Legal regulations as limitations of the addition of such components for processing and labelling of low-fat products are also crucial aspects. The modified regulations allow processors to exchange fat for added water (AW= % moisture – 4 x % protein) ensured which in total they do not exceed 40% in the final product whereas the total fat level does not exceed 30% in the USA. Price difference of products effect the consumer acceptance due to purchasing power, cultural, educational difference (Jimenez Colmenero, 2000; Allen *et al*., 1999).

Fat replacers: Most fat replacers currently in use are reformulations of previously used meat ingredients. Gums, inulin, maltodextrins, oatrim (hydrolysed oat flour), starches are used as carbohydrate-based fat replacers in meat/poultry products whereas olestra, other lipid (fat/oil) analogs (fried foods) as fat-based replacers. In fish/shellfish products, only other lipid (fat/oil) analogs (fried foods) is used as fat replacers. As carbohydrate-based fat replacers is used oat fibre replacers. Fibre can provide structural integrity, volume, moisture holding capacity, adhesiveness and shelf stability in reduced-fat products. The development and use of a wide variety of ingredients known as fat replacers are making many of these light products possible (Jones, 1996) (Table 1 and 2).

Quality evaluation of low-fat meat products: In low-fat meat products, different quality factors associated with fat reduction process have been extensively investigated with reference to those of the product with standard fat level. To gain a satisfied product properties and acceptability, it is crucial to apply the proper design specifications and suitable methodology to formulated meat products. In this context, it may classified as product and processing characteristics (Jimenez Colmenero, 2000; Pearson and Gillett, 1999; Allen *et al*., 1999.

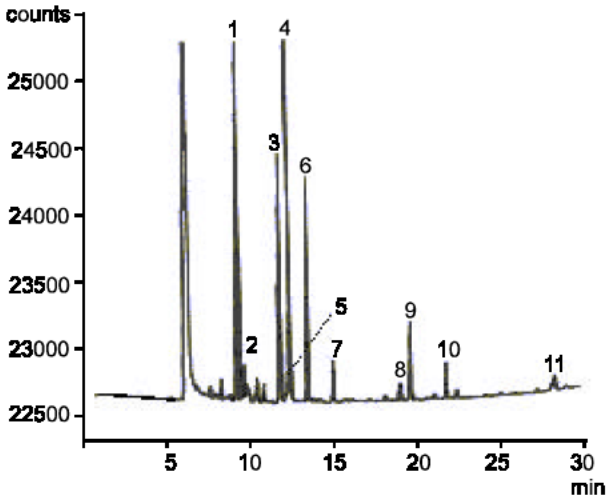

Fig. 3: Fatty acid profiles (FAs) of full fat beef patties (20% fat level) (initial case, Day = 1) and the Gas-Chromatogram properties (Tokusoglu, 2003)

Peak No.	Fatty Acid	Retention Time (min)	% of total Fatty acid
1	C16:0	10.2	23.52
2	C16:1 (n-9)	11.3	1.44
3	C18:0	12.4	16.07
4	C18:1 (n-9)	12.9	24.10
5	C18:1(n-7)	13.0	1.83
6	C18:2 (n-6)	14.1	14.42
7	C18:3 (n-3)	15.2	2.82
8	C20:3 (n-3)	19.1	1.72
9	C20:4 (n-6)	19.8	7.58
10	C20:5 (n-3)	21.8	4.16
11	C22:5 (n-3)	27.9	2.12

Product characteristics: A number of different approaches effects the fat reduction on the characteristics of processed products. One of the first aspects to be evaluated is actual composition as compared to target composition: i.e., fat, protein and moisture, and in same process added water as well. Other components such as alterations in cholesterol levels associated with fat reduction, non-meat ingredient characteristics and process treatments and conditions should be analyzed (Jimenez Colmenero, 2000; Marquez *et al.*,1989).

As relation to fat level or replacement of animal fat by vegetable oils, fatty acid profiles (FAs), saturated, unsaturated or monounsaturated FAs of meat products (Paneras and Bloukas, 1994; John *et al.*, 1986) and conjugated linoleic acid (CLA; 9c,11t-18:2) contents of low-fat meat products by Gas Chromatography (Ünal and Tokusoglu, 2002) (Fig. 3) have been performed.

Fat content and other components such as spices, smoke affects the volatile compounds responsible for flavour have been determined by headspace and nose-space analysis using Gas Chromatography-odor assessment and Gas Chromatography-Mass Spectrometry and (Chevance *et al.*, 2000; Jimenez Colmenero, 2000), by using Supercritical CO_2 extraction (Thongwong *et al.*, 1999).

Sensory analysis parameters of low-fat meat products including color, chewiness, juiciness, saltines, spiciness, smokiness, elasticity, firmness, coarseness, greasiness, overall acceptability etc., and consumer evaluation have been performed depending upon alterations factors in fat reduction process (Dreeling *et al.*, 2000; Jimenez Colmenero, 2000).

Instrumental color measurements of raw, processed meat products on the outer surface, the inner shear surface and effects of fat reduction technology on color factor has been studied (Bradford *et al.*, 1993; Brewer *et al.*, 1992). Instrumental texture analysis has also been studied by testing machine Instron, largely by compression test (Texture profile analysis, TPA) using varying percentages, penetration test, and Kramer shear press cell and Warner-Bratzler shear tests for low-fat meat products (Dreeling *et al.*, 2000; Barbut and Mittal, 1996; Dexter *et al.*,1993). In meat products, binding strength has been used to evaluate the level to that meat pieces adhere to each other whereas skin strength has been determined as a function of fat degree and substitution of vegetable oil for meat back fat (Shand *et al.*, 1994; Bloukas and Paneras, 1993).

A large number of microbiological analyses have been performed to evaluate microbial growth as aerobic, psychrotrophic bacteria (e.g. *Staphylococcus aureus*, *Enterobacteriaceae* species, *Pseudomona* ssp.), coliforms, mould or yeast populations. Hygiene conditions in composition (especially fat content and added water), processing conditions (e.g. cooking or grinding treatment, features of non-meat ingredients) on microbiological assessment have been determined (Bloukas *et al.*, 1997; Jimenez Colmenero *et al.*,1997; Egbert *et al.*, 1992).

The features of protein molecular interactions (hydrogen, hydrophobic, disulfide) in the formation of gel network matrix of high and low-fat meats have been determined and morphological features of meat products (meat emulsions or patties, restructured meats) have been performed by Light Microscopy, Scanning Electron Microscopy or Transmission Electron Microscopy (Carballo *et al.*, 1996; Goll *et al.*, 1992).

A number of different storage characteristics related to lipid oxidation levels [2-thiobarbituric acid reactive substances (TBARS)], proximate analysis, packaging conditions (plastic film and vacuum level), utilized ingredients (e.g. carrageenan, potassium lactate or olestra) and storage conditions (frozen or chilled) have

Table 1: Classified List of Major Fat Extenders, Synthetic Fat Substitutes and Combination Systems as Fat Replacers in Meat Products and Their Applications (Jones,1996).

Group	Trade/Common name	Chemical name / Composition	Concent. Used & special properties	Applications
Starch-derived	Quaker Oatrim 5Q	Enzymically hydrolyzed oat flour, typically 5%b-glucan	1-10% typically gel formed at 25% solids, used after 24h refrigeration	Processed meats
Starch-derived	Leanbid	Modified starch	-	Meat, fish and poultry products
Starch-derived	Maltrin M040-M100-M150	Corn starch maltodextrin	M040-sol. in hot H_2O and M100-readily sol. in H_2O	Meat, fish and poultry products
Starch-derived	Rice-gel L-100	Rice flour	-	Meat, fish and poultry products
Starch-derived	Slenderlean	Modified tapioca starch	1%	Sausage and ground beef products
Starch-derived	Sta-Slim L71	Modified tapioca starch (instant)	-	Meat, fish and poultry products
Starch-derived	Tapioca line range	Partially pre-gelatinized starch derived from cassava flour	2-3% in sausages	Meat products, ready meals
Starch-derived	Still-water crystals	Crystalline particles of modified golden pea carbon. (90% carbon. in that 10% dietary fiber)	Absorbs 10 fold their wt. of cold H_2O and 12 fold their wt. of hot H_2O	Processed meats
Fiber-based	Leanmaker	Oat bran and oat fiber based	%3 in low-fat meat %5 in pork sausages	Meat, fish and poultry produce. e.g. ground beef, pork sausages (Potent.-bologna, hot dogs, pizza toppings)
Fiber-based	Better Basics Advanced Oat Fibre	Oat fiber	3-6%	Processed meats
Fiber-based	P-fiber 150	Pea fiber (150 F) (Fine ground particles 30μm) Pea fiber (150 M) (Med. ground particles 200μm)	150 M/F-3% in liver paste or luncheon meat	Meats produce. (sausages, pate, liver, paste, luncheon meat)
Fiber-based	Potex-Potex PPC	Potato fiber [75% dietary fibers(cellulose, pectin, hemicellulose, lignin), 10% starch etc.]	Able: low PH, high temp., freeze-thaw	Meat products

Fiber-based	Sofalite M-176	Purification, drying and grinding of specific pea species	2-10%	Cooked sausages, pate, veget./meat/fish terrines
Protein-based	Soy Protein Concentrate	70% protein and 22% dietary fiber	3%	Meat products, patties, frankfurters, hamburgers
Protein-based	Suprorange	Isolated soy proteins	-	Meat products
Protein-based	Pea Protein	Pea protein, extracted using water and ultrafiltration	-	Meat products
Protein-based	Nutrilac HA-7570	100% milk ingredients derived	-	Meat, fish and poultry products
Gum/gels/thickeners	Aquagel-Aquavis	Carrageenan	-	Meat products
Gum/gels/thickeners	Genu carrageenan	Iota carrageenan	H_2O holding capacity/skin formation	Meat products
Gum/gels/thickeners	Konjac-N	Konjac flour (glucomannan) made from Devil's Tongue	High H_2O retention ability and weak gel/paste forming	Processed meat & fish products, sausages
Gum/gels/thickeners	Nutricol Konjac flour	Glucomannan gum obtained from tubers of Konjac plant (*Amorphophallus Konjac*) Synergism with kappa-carrageenan or xanthin gum	High H_2O retention ability and forms thermally stable gels	Ground meats

been studied according to the kind of low-fat meat product (Bloukas *et al.*,1997; Gregg *et al.*, 1993; Brewer *et al.*,1992).

Processing characteristics: Rheological behavior, pH, temperature alterations, meat particle size, mechanical action, fat distribution in the protein matrix, manufacturing procedures (design of machinery etc.), process selection and properties (cooking, curing, smoking, drying, fermentation etc.), the end-point characteristics are essential for fat reduction technology (Allen *et al.*, 1999; Jimenez Colmenero, 2000; Chin, 2000; Serdaroglu and Tömek, 1995).

Experimental design and researches needs on fat reduction process in meat products: To obtain any reformulated processed meat with desirable characteristics, several of the available technological aspects (Fig. 1) have to be combined and in some cases different treatments combined within one of these aspects. Also, to obtain the best formulations, it should try out a large number of different combinations. Due to such an approach is time consuming and too costly, it should develop the optimized experimental design for low-fat meat products. According to Arteaga *et al.* (1994) and Jimenez Colmenero (2000), optimization is the choice of a best alternative from a specific set of options.

The optimization process must be such as to allow selection of the combination of the various different fat reduction procedures that best suits the accepted concept of the product (Jimenez Colmenero, 2000). In optimization process, particular problems in the form of constraints may limit the some values of factors (fat reduction technologies such as fat degree, percentage of non-meat protein or final temperature of cooking, responses such as shelf-life acceptability score that is parameter to be optimized. The possibility of interactions between technological factors must be taken into account in the case that simultaneously applying options which can effect product properties (Jimenez Colmenero, 2000). The effect occurred via an applied technological process or the addition of an ingredient may not only be effected by the application of different process or the addition of different ingredient, but it may

Table 2: Classified List of Major Fat Replacers in Meat Products and Their Applications (Jones, 1996).

Group name	Trade/common name	Chemical name/composition	Concent. Used &special Properties	Applications
Fat extenders	Prime-O-Lean Prime-O-Lean Vit (or Algesteren)	P-O-L- Mix of canola oil, beef proteins, tapioca flour, and H_2O P-O-L-Vit- Mix of H_2O, partially hydrogenated canola oil, wheat gluten, tapioca starch, egg white, sodium alginate, lecithin and flavor	<25% Replacement for animal fat	Ground meat products e.g. sausages, hamburgers, processed meats
Synthetic Fat Substitutes	Olestra (sucrose polyester)	Mixture of hexa-to octa-esters of sucrose with naturally occurring fatty acids (C_8 to C_{22})	Non-digestible Non-caloric	Processed meats
Synthetic Fat Substitutes	Alkoxylated alkyl glucosides esterified with fatty acids	Alkoxylated alkyl glycosides esterified with fatty acids, e.g., ethyl glucoside tetra acetate, ethyl maltoside polyoleate	Non-digestible Non-caloric	Meat products Meat products with frying oils
Synthetic Fat Substitutes	Diol lipids	Diol lipids-ethylene glycol esters of fatty acids and derivatives (e.g., long chain diol esters)	Partially digestible; 0.5-8.5 kcal/g.	Meat products
Combination Systems	Bindtex	Carrageenan, dairy protein	-	Developed for low-fat meat applications
Combination Systems	Carra Fat	H_2O carrageenan, salt, flavoring	Emulsified solid gel (ca.90% H_2O; 4 weeks shelf-life under refrigeration	Meat, fish and poultry products
Combination Systems	Fat Replacers 785 Fat Replacers 786	785 - Combination of carbohydrates (maltodextrins and vegetable fiber), stabilizers (carrageenan, CMC) and flavor 786-785 + Egg albumen	-	Meat products-burgers, sausages, liver pate
Combination Systems	Fat-Tastic	Carrageenan, H_2O, salt, and flavors; pre-hydrated and gelled	5-15%. Also available in dry powder form and based on modified starch instead of carrageenan	Meat products e.g.-ground beef, pork sausages Non-carrageenan version-hot dogs, bologna

also depend on the medium where this takes place-fat, water or protein content, ionic strength etc. In the low-fat meat product development, complete factorial design and central composite rotatable design are extensively used experimentally (Jimenez Colmenero, 2000).

Sensory, nutritional, hygienic aspects, consumer acceptability, cost, regulation, marketing, convenience, ethics been widely crucial for the structure of reformulated meat products. On the view of point, raw meat quality, the selection of proper non-meat ingredient, the choice of process conditions are essential for the final product quality. Further studies are needed to try the non-meat different ingredients such as fiber-based, starch-derived, protein-based, synthetic fat substitutes, fat extenders and combination systems and are needed the substantiate the efficacy of those compounds in the specific fat reduction processing. Obtained product from new technologies needs not only enhanced quality but also more economical and less time-consuming. For product optimization, reaction products should be monitored in all steps by instrumental, sensory and microbiological assessment during the experimental design. One of the quality assurance produres is HACCP utilization is crucial in reformulated meats and new formulated product also needs legal regulations as standardization based on the categories and the composition which the nomenclature implies in each case.

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