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Review paper

Health aspects of dry-cured ham

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A b s t r a c t: Different factors (pig breed, animal production practices) are responsible for nutritional characteristics of pork and dry-cured hams thereof, and their potential effects on human health. Traditional production of dry-cured ham is very popular all over Europe (Vrsacka ham, Iberian ham, Serrano ham, Corsican ham, Parma ham, Modena ham, Nazionale ham, San Daniele ham etc.). Dry-cured ham is an important source of biologically valuable proteins, iron, B-complex vitamins, and phosphorus. Although the potential role of meat products, including such traditionally produced hams, in the healthy human diet have not been completely clarified, many studies are starting to draw a picture of their impact on human health. The object of this review was to provide an analysis of the nutritional composition, including some micronutrients and vitamins, of traditionally produced dry-cured ham and the role these meat products could play in a healthy diet.

Keywords: *dry-cured ham, health, nutritional composition, micronutrient supply.*

Introduction

Pork is recognized as a food with essential nutritional properties because it is an important source of proteins, minerals and fats (*Baltic et al.*, 2014; *Boskovic et al.*, 2015; *Jiménez-Colmenero et al.*, 2001; *Jiménez-Colmenero et al.*, 2010; *Kauffman*, 2001; *Lucarini et al.*, 2013; *Reig et al.*, 2013). However, pork also contributes to the intake of fat, saturated fatty acids, cholesterol, and other substances that, in inappropriate amounts, can have negative physiological effects on human health (*Toldrá and Reig*, 2011).

Red meat (100 g) contains about 20–24 g of protein in the raw state or 27–35 g of heat-treated protein (*Wyness et al.*, 2011). Meat contains eight essential amino acids and histidine, an essential amino acid for children (*Higgs*, 2000; *Wyness et al.*, 2011). Essential amino acids play a role in muscle tissue regeneration after injuries or surgery (*Boskovic et al.*, 2015; *Higgs*, 2000). Some healthy components of meat and their target markers are presented in Table 1.

The fat content in meat varies widely depending on various factors including animal feeding system, meat cut, cooking conditions etc. The fatty acid composition of pork has an important effect on the diet/health relationship for pork consumers. Among pork lipids, less than 50% constitutes saturated fatty acids (SFAs) (*Jiménez-Colmenero et al.*, 2001).

Dietary fatty acids in pig feed are incorporated unchanged into pig adipose tissue (*Jakobsen*, 1999; *Toldrá et al.*, 1996). The extent of incorporation can vary depending on the specific fatty acid and the type of feed. Different types of dietary oils and their effects on the proportions of fatty acids have been studied (*Reig et al.*, 2013). The use of linseed oil in pig feed increased the n-3 fatty acid content. It significantly increased the linolenic acid (C18:3n-3), slightly increased the eicosapentaenoic (C20:5n-3, EPA) and docosahexaenoic (C22:6n-3, DHA) acids, and decreased the linoleic acid (C18:2n-6) in pork (*Jiménez-Colmenero at al.*, 2006; *Reig et al.*, 2013). Other dietary oils such as soy, peanut, corn, and sunflower oil increased the content of linoleic acid (C18:2n-6). The addition of fish oils increased the content of EPA and DHA and reduced the n-6/n-3 ratio to almost 2 (*Irie and Sakimoto*, 1992; *Jakobsen*, 1999; *Reig et al.*, 2013). Also, some studies investigated incorporation of omega-3 fatty acids in meat because of their ability to reduce the level of low density lipoproteins (LDL), cholesterol and blood triacylglycerols (*Harris*, 2007; *Markovic et al.*, 2015).

When pig feed is rich in saturated fats, the levels of palmitic (C16:0), palmitoleic (C16:1),

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Table 1. Healthful components of meat products (adapted from *Olmedilla-Alonso et al.*, 2013)

Target markers	Compounds associated with beneficial effect
Cardiovascular	
Lipids	MUFA, PUFA, CLA, dietary fibre, vitamin C, vitamin E, bioactive peptides, L-carnitine
Blood pressure	bioactive peptides
Obesity	CLA, dietary fibre
Other	Folic acid, vitamin B6, vitamin B12, lycopene
Cancer	Selenium, CLA, folic acids
Bone diseases	Calcium, magnesium
Anemia	Iron
Growth	Iodine

Legend: MUFA – monounsaturated fatty acids; PUFA – Polyunsaturated fatty acid; CLA – Conjugated linoleic acid

stearic (C18:0) and oleic (C18:1) acids in pork are significantly higher and the PUFA/SFA ratio is lower (*Leszczynski et al.*, 1992; *Morgan et al.*, 1992; *Reig et al.*, 2013). Feed rich in linoleic acid, an n-6 fatty acid which is most commonly found in soy, corn, maize, sunflower and barley, resulted in pork with significantly increased concentrations of this fatty acid (*Larick et al.*, 1992; *Toldrá et al.*, 2004). The content of conjugated linoleic acid (CLA) can also vary depending on the feed type. CLA has potential benefits for human health (anticarcinogenic, antidiabetic and antiatherogenic effects) (*Lauridsen et al.*, 2005; *Schmid et al.*, 2006; *Reig et al.*, 2013). Studies with CLA added to pig feed had the goal of increasing the CLA content in pork. *Ivanovic et al*. (2015) added the recommended 2.0% CLA to pig feed and reported 3.56±0.71% CLA (c9t11CLA+t10c12CLA) in the muscle tissue, while the control pork from pigs without added dietary CLA did not contain detectable CLA. Similar results were reported with 1% CLA added to pig feed which resulted in CLA levels in muscle tissue of 5.5 mg 100 g^{-1} (*Eggert et al.*, 2001).

As a major source of high quality proteins, meat and meat products are one of the most highly investigated sources for isolation of bioactive peptides in recent years (*Baltic et al.*, 2014; *Ryan et al.*, 2011). Bioactive peptides have a range of potential positive effects on human health, such as antioxidative, antimicrobial, antihypertensive, antithrombotic, cytomodulatory, immunomodulatory, anticancer, hypocholesterolemic and anti-obesity effects, which mainly depend on their structure. Considering the activities of bioactive peptides and their wide-spectrum benefits to human health, it is clear that these peptides could be suitable candidates to be used for health promotion and disease risk reduction (*Baltic et al.*, 2014). In addition to myosin and actin being used for peptide generation, other proteins originating from thick and thin filaments and from connective tissue like fibrillar collagen can be used (*Udenigwe and Ashton*, 2013).

The iron content in pork is quite constant as is the content of the trace elements selenium, magnesium and zinc (*Reig et al.*, 2013). Also, pork contains folate, vitamin B12 and vitamin A, all cancer protecting factors (*Bieasalski*, 2005). Pork contains about 1.8 mg iron, 2.6 mg zinc per 100 g, and meat can provide up to 50% of the Recommended Dietary Allowances (RDA) for iron, zinc, selenium, vitamins B12, B1, B2, B6 and 100% of vitamin A (*Bieasalski*, 2005).

Ham components and health implications

Dry-cured ham is a typical meat product in the Mediterranean area, but also in many other countries, including the United States and Japan (*Bermúdez et al.*, 2012; *Jiménez-Colmenero et al.*, 2010; *Lucarini et al.*, 2013; *Marusic et al.*, 2013; *Toldra and Reig*, 2011). The differing manufacturing features applied in dry-cured ham production result in chemical composition differences (*Lucarini et al.*, 2013). However, many factors affect the physico-chemical and nutritional aspects and also sensory properties of ham, including the rearing system,

Table 2. Chemical composition of traditional dry-cured hams from Italy, Serbia and Montenegro (adapted from *Lucarini et al.*, 2013)

Traditional ham	Moisture	Ash	Proteins	Lipids	Energy Kcal portion^{-1}, 50 g
	g 100 g^{-1} (%)				
Italy					
Modena	45.6±3.0	5.8±0.6	25.6±1.6	22.9±3.5	154
Nazionale	50.5±3.2	6.6±1.4	27.8±2.5	13.7±5.1	117
Parma	50.3±2.0	5.5±0.4	25.9±1.5	18.3±2.8	134
San Daniele	50.2±2.1	5.3±0.5	25.7±1.4	18.6±2.8	135
Serbia					
Vrsacka*	51.65	4.97	32.82	10	99
Montenegro					
Dry-cured ham from Martex company	49.61	4.71	31.02	14.61	128

* Chemical analyses of Vrsacka ham and dry-cured ham (Martex) were according to ISO standard methods (moisture - ISO 1442:1998; ash- ISO 936:1998, proteins - ISO 937:1978, lipids- ISO 1444:1996

animal age, pig genotype, as well as processing conditions (*Andrés et al.*, 2004).

Table 2 shows moisture, ash, protein, lipid and energy content of the most popular dry-cured hams from Italy, Serbia and Montenegro. Dry-cured ham is a good source of proteins (25.6–32.82 g 100 g^{-1}) and lipids (9.56–22.9 g 100 g^{-1}). The content of free amino acids in dry-cured ham rises during processing as a result of proteolysis (*Alfaia et al.*, 2004; *Jiménez- Colmenero et al.*, 2010; *Toldra et al.*, 2000). Some of the amino acids in dry-cured ham, like taurine, glutamine, tryptophan, leucine and valine, can have benefits for human health (*Ventanas*, 2006).

Figure 1 Vrsacka ham (*Baltic et al.*, 2015a)

Vrsacka ham contains about 33% protein, which is higher than the protein content of dry-cured ham from Italy (Table 2). The fat content of Vrsacka ham is lower than that of Italian hams. This Serbian ham has a designated protected geographical indication (PGI) (http://www.zis.gov.rs) (Figure 1).

Nevertheless, the main factor that determines ham price is the fattening diet for the animals (*Narváez-Rivas et al.*, 2011). Furthermore, there is an increased awareness about the need for more "healthy" fats in the human diet that has focused research on the nutritional characterisation of fat from different meat products.

There are studies which show that dietary fat content plays a significant role in prevention of some chronic disorders (*Jiménez-Colmenero et al.*, 2010). The World Health Organization (*WHO*, 2003) recommended an optimal intake of total unsaturated fatty acids (between 15–30% of total diet energy), for SFA to be no more than 10% of dietary energy, and polyunsaturated fatty acid (PUFA) to be between 6–10% of dietary energy. Many studies provide results about fat and fatty acid profiles in dry-cured ham (*Gandemer*, 2009; *Lo Fiego et al.*, 2005; *Santos et al.*, 2008; *Ventanas et al.*, 2007). The total *trans* fatty acid content in the human diet should be less than 1% (*World Health Organization*, 2003). The results of different studies suggest that dry-cured ham is a healthy food and can be consumed as a regular diet component (*Fernández et al.*, 2007; *Jiménez-Colmenero et al.*, 2009).

Table 3. Fatty acid profile (% of total fatty acids) of the different types of dry-cured ham (commercial feeding system) (adapted from *Jiménez-Colmenero et al.*, 2010)

Ham	SFA	MUFA	PUFA	P/S*	n-6/n-3
Iberian (Spain)	35.15	51.39	13.44	0.38	31.2
Serrano (Spain)	32.70	52.7	10.2	0.31	16.2
Bayonne (France)	36.4	52.9	10.7	0.29	14.1
Corsican (France)	34.9	55.4	9.7	0.28	8.7
Parma (Italia)	35.99	54.04	8.59	0.23	39.9
San Daniele (Italia)	38.5	51.9	9.6	0.25	–
Jinhua (China)	37.10	46.63	14.24	0.38	–

* P/S – PUFA/SFA ratio

On average, the fatty acids in dry-cured ham comprise 35–40% SFA, 45–50% MUFA and 10–15% PUFA (Table 3). Many nutritionists currently tend to focus more on the PUFA/SFA ratio and the n-6/n-3 PUFA ratio than on individual levels of fatty acids. The PUFA/SFA ratio in dry-cured ham ranges from 0.23 to 0.38 (Table 3). Note that a high amount of PUFA is not necessarily healthy, especially if the n-6/n-3 ratio is not balanced. *Simopoulos* (2002) presented an argument that the n-6/n-3 ratio should not exceed 4, while the *British Nutrition Foundation* (1992) stated that the n-6/n-3 ratio should be <6. When the n-6/n-3 ratio is very high, it can promote cancer, autoimmune and inflammatory diseases (*Simopoulos*, 2002). Genetic and feeding strategies have proven to be effective in supporting production of dry-cured ham with good PUFA/SFA and n-6/n-3 ratios, and therefore, with desirable fat characteristics (*Bermúdez et al.*, 2012).

Dry-cured ham is a good source of iron, zinc, potassium, magnesium and selenium (Table 4), which is particularly important for the nutrition of pregnant women and children (*Benoist*, 2001). It contains iron levels of 1.8–3.3 mg 100 g^{-1} (Table 4). Dry-cured ham contains zinc at levels of 2.2–3.0 mg 100 g^{-1} (Table 4), an essential element in nutrition, as it is involved in the activity of more than 200 enzymes (*Neumann et al.*, 2002). Magnesium is important, especially in the prevention of cardiovascular diseases and osteoporosis (*Fleet and Cashman*, 2003). The magnesium content in dry-cured ham depends on the pig diet and the type of salts added, such as magnesium aspartate, magnesium aspartate hydrochloride or magnesium fumarate (*D'Souza et al.*, 1999). Selenium is an important trace element in the human diet, because of its role in antioxidative processes in the human body (*Higgs*, 2000). Many studies have shown the influence of selenium added to feed on pork quality (*Baltic et al.*, 2015b; *Gjerlaug-Enger et al.*, 2015; *Naik et al.*, 2015). Pork can be enriched with selenium through dietary supplementation of pig feed with sodium selenite or selenium-rich yeast.

In addition, dry-cured ham contains a high level of the B-complex vitamins, whereby the nutritional profile of this vitamin group depends on the raw meat vitamin content and manufacturing procedures (*Lucarini et al.*, 2013). Vitamin B6 is one of the major vitamins from this group in pork (*Ball*, 1994). *Higgs* (2000) presented data showing that animal origin foods are the only dietary source of vitamin B12. Also, dry-cured ham is a source of tocopherol (vitamin E, important in prevention of cardiovascular diseases). Vitamin E is a very effective antioxidant because it is accumulated in tissues and subcellular structures, including membranes. Pig muscle can be enriched with vitamins E and A through their supplementation in pig feed. Depending on the concentration (usually about 100–200 mg kg^{-1} of feed) and supplementation duration (several weeks prior to slaughter) the content of these vitamins in the muscles may be proportionally increased (to the value of almost 13 mg kg^{-1} of dry muscle) (*Isabel et al.*, 2003; *Mercier et al.*, 1998). Vitamin E tends to deposit in the muscles of the thoracic limb and neck (*O'Sullivan et al.*, 1997).

Table 4. Content of trace elements and vitamins (mg 100 g^{-1} and µg 100 g^{-1}) in traditionally-produced dry-cured ham (adapted from *Jiménez-Colmenero et al.*, 2010*; Lucarini et al.*, 2013)

Parameter	Italian ham	Serbian ham (Vrsacka)	All types of traditional ham (included Spanish ham), per 100 g	Montenegro ham
Ca (mg)	/	/	12–35	/
Fe (mg)	0.92–1.05	1.8	1.8–3.3	2.2
Zn (mg)	2.08–2.72	2.2	2.2–3.0	4.3
Mg (mg)	/	/	17–18	/
K (mg)	/	/	156–160	/
Cu (mg)	/	0.03	/	0.03
Mn (mg)	/	0.01	/	0.01
P (mg)	/		157–180	
Se (µg)	11–17	14	29	17
Na (mg)	/	/	1100–1800	/
Thiamine (B1) (mg)	0.58–0.90	/	0.57–0.84	/
Riboflavin (B2) (mg)	0.19–0.22	/	0.20–0.25	/
Niacin (B3)	5.13–5.90	/	4.5–11.8	/
Vitamin B6 (mg)	1.0–1.13	/	0.22–0.42	/
Folic acid (µg) (B9)	/	/	/–13.49	/
Vitamin B12 (µg)	0.33–0.67	/	/–15.68	/
Vitamin E (mg)	0.11–0.24	/	0.08–1.5	/

Legend: Fe, Cu, Mn, Zn analyses of Vrsacka ham and dry-cured ham (Martex) were according to ISO 6869:2008; Se analysis according to ISO 16159:2012

Dry-cured ham contains several endogenous antioxidants (ubiquinone, ascorbic acid, uric acid, spermine, carnosine, anserine) (*Decker et al.*, 2000). Ubiquinone (Coenzyme Q10) has an effect on gene expression (*Mattila et al.*, 2000), ameliorating endothelial function (*Belardinelli et al.*, 2006), and it is considered as a bioactive compound (*Marusic et al.*, 2013). Many meat compounds have been identified as antioxidant regulating substances.

Carnosine and anserine are know as antioxidants in meat and they are absorbed into the blood plasma intact (*Marusic et al.*, 2013). These dipeptide antioxidants are involved in xenobiotic metabolism and protection against free radicals and oxygen toxicity (*Winters et al.*, 1995). Dipeptides help oxidation control through prevention of lipid oxidation (*Decker and Crum*, 1993). Also, they reduce rancid tastes and improve colour stability in finished hams (*Jiménez-Colmenero et al.*, 2010). Research into the effects of these substances in dry-cured ham and their potential benefits for human health is currently in progress.

The major source of free L-carnitine (an amino acid derivative) for humans is meat and meat products. L-carnitine plays a role in energy production processes (*Marusic et al.*, 2013), helps the human body to absorb calcium and protects skeletal muscle (*Demarquoy et al.*, 2004). Creatine (another amino acid derivative) is a key substance in muscle, particularly involved in the transfer of high energy phosphate to ADP in muscle cells (*Wyss and Kaddurah-Daouk*, 2000).

Feeding and management plan for pig production with potential health implications

There are numerous factors in pig breeding and management that affect the content of many important substances in pork, which should be taken into consideration (*Reig et al.*, 2013). Genetic strategies and pig selection are based on morphological parameters of pure Iberian breed or white sows. Duroc origin pork contains more intramuscular fat than pork from European white breeds (*Carrion et al.*, 2004). Also, in recent years, there has been growing interest of producers in the genotyping of pigs used for dry-cured ham production. Genetic strategies can improve the fatty acid profile of dry-cured ham (and other pork products) (*Lai et al.*, 2006).

The chemical composition of pork, and especially the fat content, is a polygenetically determined characteristic (*Carrion et al.*, 2004). However, the chemical composition of pork is also related to the pig population genotype, nutrition and feeding management (*Garnier et al.*, 2003). Numerous studies indicate that loin and ham from Iberian pigs contain significantly higher amounts of intramuscular fat that those cuts in Landrace pigs (*Ventanas et al.*, 2007). Also, the dietary fatty acid composition provided by the pig feed is an extremely important contributor to the fatty acid profile of the resultant pork. *Jiménez-Colmenero et al*. (2001) showed that increased amounts of unsaturated fatty acids in meat increased the possibility of oxidation. All strategies based on pig production make it possible to increase concentrations of beneficial and reduce concentrations of detrimental components in pork, in order to improve human health.

Reduced fat, cholesterol and sodium content, plus reduced calories are among the most common targets for reformulation of pork products with the aim of positively influencing human health (*Jiménez-Colmenero et al.*, 2001). Fat reduction can be achieved by combining pre-selected raw pork meat. The cholesterol content can be reduced by replacing fat with other vegetable materials (peanut, canola, sunflower, olive), without cholesterol. Finally, the salt content can be reduced by using lactates and collagen hydrolysates as flavour enhancers.

Conclusion

Dry-cured ham has potential to be a component of a healthy human diet, as it contains important essential amino acids and micronutrients (trace elements and minerals). During the dry-cured ham production process, the amino acid content in the product actually increases due to proteolysis. Therefore, these meat products should be recommended in the human diet, especially for groups with special dietary requirements. (pregnant women and growing children). However, dry-cured ham cannot be recommended for hypertensive consumers, because of its high salt content.

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