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A meta-analysis of the effect of pasture access on the lipid content and fatty acid composition of lamb meat

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ABSTRACT

A meta-analysis on the influence of the pasture on the lipid content and fatty acid profile in lamb meat was conducted. A total of 20 studies were selected and data on total lipid content, saturated, mono- and polyunsaturated fatty acids in lamb meat were extracted for two population groups, indoors, and pastured. Due to the high between-study heterogeneity, separate random-effects models were applied to the raw mean difference (effect size parameterization) for each of the outcomes. The results of the meta-analysis pointed that access to pasture tended to decrease the fat content in lamb, while increasing the saturated fatty acids ($P < 0.05$). The amounts of monounsaturated and n-6 polyunsaturated fatty acids were decreased ($P < 0.05$). On the other hand, grazing led to substantial increase in the content of n-3 polyunsaturated fatty acids, and decrease ($P < 0.01$) of the ratio n-6/n-3 in lamb meat, thus suggesting that pasture rearing can be recommended for improvement of meat dietetic quality.

1. Introduction

Meat is an important component of a healthy human diet. However, besides the considerable amount of protein, vitamins, and minerals that it provides, meat is also a major source of fat. Although improving the sensory quality, the increased amounts of fat in meat, especially rich in saturated fatty acids, might have negative effect on the human health since its over-consumption is associated with higher risk of obesity, diabetes, and cardiovascular disease. Meat from ruminant animals has relatively high content of saturated fatty acids due to the biohydrogenation process, and hence considered less healthy. Although the possibilities to alter the fatty acid composition in ruminants are much more limited than in monogastric animals, numerous investigations focus on the ways of dietary manipulation of the lipid profile through various ruminant feeding strategies or rearing systems.

The beneficial effect of pasture rearing on the lipid profile in ruminant meats, mainly through increasing the content of n-3 polyunsaturated fatty acids, has been reported (Gatellier, Mercier, & Renerre, 2004; Cividini, Levart, & Zgur, 2008; Cividini, Levart, Žgur, & Kompan, 2014). Furthermore, some reviews addressing the effects of various rearing systems or feeding on the fatty acid profile in meat are available (Bas & Morand-Fehr, 2000; Wood et al., 2008), based on synthesis of the results from individual studies. However, as only few quantitative methods are applied to those synthetic reviews, they become narratives with subjective and qualitative summaries, which draw the conclusions based on the results of null hypothesis significance testing and do not account for the variability between primary studies as in Osenberg and St. Mary (1998) or Sales (2009).

Using meta-analysis allows to quantitatively estimate the effects and their precision as calculated from the results of individual research studies, even with opposite results (Fernandez-Duque, 1997) and to describe the overall strength of the effect, and in which circumstances that it is stronger or weaker (DeCoster, 2004). Additionally, according to Carriquiry, Weber, and Crooker (2008), meta-analysis might be particularly useful when small sample sizes limit statistical power of individual studies to detect differences. The aim of the present study was to quantify the effect of pasture access on the total intramuscular lipid content, as well as the content of saturated, monounsaturated, and polyunsaturated fatty acids in lamb meat.

2. Material and methods

2.1. Literature search and selection of studies

Extensive computerized literature search through Web of Science, PubMed, Scopus databases, publishers' websites, and Google was performed to select studies assessing the effect of pasture vs. indoors

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rearing on the content of intramuscular lipids and fatty acid composition in lamb meat. Keyword combinations of "lamb", "fatty acid", "fatty acid composition", "meat", and "pasture" were used in the search. As the first requirement for inclusion in the meta-analysis, the primary studies had to be published as peer-reviewed articles or conference proceedings in English, Portuguese or French. Each observation in the meta-analysis corresponded to the mean or least-squares mean of each treatment group (i.e., pasture and indoors rearing). The variables or outcomes extracted from each of the primary studies were: intramuscular fat content (TL), saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), polyunsaturated fatty acids (PUFA), n-3 and n-6 polyunsaturated fatty acids (n-3 PUFA, n-6 PUFA), and the ratio n-6/n-3 in the lamb meat. The selected publications were further required to provide any measure on intra-experiment variation, expressed either as standard error (SE) or standard deviation (SD) of the mean of each treatment group, or alternatively as mean square error (MSE) or root mean square error (RMSE).

2.2. Description of data sets

After assessing all available information, a total of 20 studies, providing appropriate data and measures of variance for the outcomes, were deemed suitable for inclusion in the meta-analysis (Table. 1). The rearing conditions of the animals on concentrate diets were described mostly as indoor (Aurousseau et al., 2007; Joy, Ripoll, & Delfa, 2008; Kaczor, Borys, & Pustkowiak, 2010; Nürnberg et al., 2001; Nuernberg et al., 2005; Popova, 2007; Popova & Marinova, 2013; Popova, 2014) or drylot (Cañeque et al., 2003; Panea, Carrasco, Ripoll, & Joy, 2011; Rowe, Macedo, Visentainer, Souza, & Matsushita, 1999; Velasco et al., 2001). Sheepfold was used by Diaz et al. (2002) and Santé-Lhoutellier, Engel, and Gatellier (2008), while feedlot was used by Rhee, Lupton, Ziprin, and Rhee (2003a,b). In the studies of Luciano et al. (2012) and Scerra et al. (2011), lambs were stall-fed, while Fernandes et al. (2010) and Guler, Aktumsek, and Karabacak (2011) referred to the 'control' and 'treatment' as 'confined' and 'concentrate' groups, respectively. The composition of concentrates fed to the lambs was reported in twelve studies. They were mostly based on barley (Aurousseau et al., 2007; Kaczor et al., 2010; Luciano et al., 2012; Scerra et al., 2011), maize (Guler et al., 2011; Popova, 2007; Popova, 2014; Popova & Marinova, 2013) while in the experiments of Rhee et al. (2003a,b), the main ingredient of the indoors diet was sorghum. Five of the studies reported results from experiments with suckling lambs (Joy et al., 2008; Nuernberg et al., 2005; Panea et al., 2011; Velasco et al., 2001), while Aurousseau et al. (2007) used both weaned (on pasture) and not weaned (for the indoor). The weaned lambs having access to pasture grazed either pasture alone (Aurousseau et al., 2007; Fernandes et al., 2010; Guler et al., 2011; Luciano et al., 2012; Nürnberg et al., 2001; Rowe et al., 1999; Santé-Lhoutellier et al., 2008; Scerra et al., 2011) or received concentrate as the indoors lambs (Cañeque et al., 2003; Diaz et al., 2002; Kaczor et al., 2010; Rhee et al., 2003a,b; Popova, 2007; Popova, 2014; Popova & Marinova, 2013). Most of the studies determined the lipid content and fatty acid composition in m. *Longissimus dorsi*, more specifically *Longissimus thoracis* (Aurousseau et al., 2007; Joy et al., 2008; Scerra et al., 2011; Velasco et al., 2001), *Longissimus lumborum* (Cañeque et al., 2003; Fernandes et al., 2010; Kaczor et al., 2010; Popova, 2007). Rhee et al. (2003a,b) used samples of m. *Semimembranosus*.

2.3. Data analysis

To summarize the influence of access to pasture and indoors rearing on a given outcome variable (TL, SFA, MUFA, PUFA, n-3, n-6 PUFA or the ratio n-6/n-3 in lamb meat), for each of the primary studies the effect size measure of such outcome ($ES_{outcome}$) was calculated as:

$$\mathrm{ES}_{\mathrm{Outcome}} = \overline{\mathrm{Outcome}}_{\mathrm{indoors}} - \overline{\mathrm{Outcome}}_{\mathrm{pastured}}.$$

Thus, the effect size method allows the comparison of the means of the outcomes measured for the two population groups, indoors, and pastured. The parameterization of raw difference between means (D) is the most obvious and basic estimate of the effect size (Borenstein, Hedges, Higgins, & Rothstein, 2009). According to some researchers, it is sufficient and even superior to other ways of parameterization of the effect size (Baguley, 2009; Wilkinson and the APA Task Force on Statistical Inference, 1999). It enables an easy comparison of results with other studies using the same measurement (Fritz, Morris, & Richler, 2012). For each of the primary studies, the asymptotic standard error of the effect size was calculated as:

$$SE_D = \sqrt{\frac{n_1 + n_2}{n_1 n_2} S^2_{pooled}}.$$

Where n_1 is the sample size of the pastured group, n_2 the sample size of the indoors group, s^2_{pooled} is the pooled standard deviation.

Table 1
Description of the primary studies included in the meta-analysis.

Reference	Country	Breed	Weaned	Live weight at slaughter	Trial period (access to pasture)	Observed outcome*
Aurousseau et al., 2007	France	Ile de France	Yes	34.5	109	TL, SFA, MUFA, n-3, n-6, n-3/n-6
Cañeque et al., 2003	Spain	Talaverana	Yes	28.0	46	SFA, MUFA, PUFA
Diaz et al., 2002	Spain	Talaverana	Yes	24.0	58	TL, SFA, MUFA, PUFA, n-6/n-3
Fernandes et al., 2010	Brazil	Suffolk	Yes	32.0	87	MUFA, PUFA, n-3, n-6
Guler et al., 2011	Turkey	Akkaraman	Yes	40.6	90	SFA, MUFA, PUFA, n-3, n-6, n-6/n-3
Joy et al., 2008	Spain	Churra Tensina	No	23.0	80	TL, SFA, MUFA, PUFA, n-3, n-6, n-6/n-3
Kaczor et al., 2010	Poland	Koluda, Il de France × Koluda	Yes	35.5	40	TL, SFA, MUFA, PUFA, n-3, n-6/n-3
Rhee et al., 2003a	USA	Merino × Rambouillet	Yes	59.0	168	SFA, MUFA, PUFA
Rhee et al., 2003b	USA	Rambouillet	Yes	59.0	108	SFA, MUFA, PUFA
Luciano et al., 2012	Italy	Merinizzata Italiana	Yes	19.83	92	TL, PUFA
Nürnberg et al., 2001	Germany	Rough wool Pomeranian Landrace	Yes	40.0	107	TL, SFA, n-3, n-6, n-6/n-3
Nuernberg et al., 2005	Germany	Black Head × Gotland	No	40.0	115	TL, SFA, PUFA, n-3, n-6, n-6/n-3
Panea et al., 2011	Spain	Churra Tensina	No	22.0	74	TL, SFA, MUFA, PUFA, n-6/n-3
Popova, 2007	Bulgaria	Zapadnostaroplaninska	Yes	19.3	60	TL
Popova, 2014	Bulgaria	North Eastern Bulgarian Fine wool	Yes	31.5	73	SFA, MUFA, PUFA
Popova & Marinova, 2013	Bulgaria	North Eastern Bulgarian Fine wool	Yes	31.5	73	TL
Rowe et al., 1999	Brazil	Corriedale, Bergamacia × Corriedale, Hampshire Down × Corriedale	Yes	30.0	na	TL, SFA, MUFA
Santé-Lhoutellier et al., 2008	France	Texel × Romanov	Yes	30.9	169	TL, SFA, MUFA, PUFA, n-3, n-6
Scerra et al., 2011	Italy	Italian Merino	Yes	na	89	TL, SFA, MUFA, PUFA, n-3, n-6, n-6/n-3
Velasco et al., 2001	Spain	Talaverana	No	14	na	TL, SFA, MUFA, PUFA, n-6/n-3

* TL: total lipids, SFA: saturated fatty acids, MUFA: monounsaturated fatty acids, PUFA-polyunsaturated fatty acids.