Section G

Livestock diversity and human nutrition

1 Introduction

Genetics has a major influence on the composition of animal-source foods (primary foods, such as meat, offal, milk and eggs, and products such as cheese and sausages). Foods obtained from different animal species differ, to varying degrees, in both their macronutrient and their micronutrient compositions. Nutrient composition is also affected by processing methods and, in the case of meat, is affected by the particular cut or part of the animal from which it comes. Meat from one species can contain more than twice as much fat as the equivalent cut from another species. For example, pork loin (taking the lean part of the cut into consideration) contains 2.2 g of fat/100 g edible portion on a fresh weight basis (EP), while the equivalent figure for beef loin is 5.1 g/100 g EP. The iron content of pork liver is 23.3 mg/100 g EP, while that of beef liver is less than 5 mg/100 g. Further examples are shown in Table 1G1.

This section focuses on the influence of genetics on the nutritional contents of raw primary animal-source foods. The first subsection below discusses the increasing interest in food biodiversity witnessed in recent years and the degree to which this trend has extended into the livestock sector.[1] This is followed by a look at efforts that have been made to assemble and disseminate information on the topic and then by an overview of the state of knowledge regarding the potential significance for human nutrition of genetic influence on the composition of animal-source foods. The final subsection identifies some research priorities in this field.

2 Growing interest in food biodiversity

While nutritional differences between foods obtained from the most widely used livestock species (cattle, pigs, chickens, sheep and goats) have been relatively well documented, less attention has been paid to foods obtained from other species and to differences between products obtained from different breeds within species. Recent years have, however, seen growing interest in food biodiversity. For example, in 2006, the Convention on Biological Diversity adopted a framework for a cross-cutting initiative on biodiversity for food and nutrition (CBD, 2006). In 2007, the Commission on Genetic Resources for Food and Agriculture decided to integrate work on biodiversity and nutrition into its Multi-Year Programme of Work (FAO, 2007b). Food biodiversity in this context is defined as “food identified at the taxonomic level below the species level, and underutilized or wild species” (FAO, 2013a).

While work on food biodiversity is less advanced in animals than it is in plants, some studies have looked at nutritional differences between cattle milk and milk from “underutilized” species. For example, horse milk has been shown to be lower in fat than cattle milk. Moreover, the fatty-acid profile of milk from these two species is different, with horse milk being higher in total n-3 fatty acids.

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[1] The inclusion of this section devoted to livestock diversity and human nutrition, for which there was no equivalent in the first report on *The State of the World’s Animal Genetic Resources for Food and Agriculture* (first SoW-AnGR) (FAO, 2007a), is an indication of this growing interest.

TABLE 1G1

Nutrient composition of selected animal-source foods

Animals-source foods	Energy*	Moisture	Protein	Fat	Available carbo-hydrates**	Ash	SFA	MUFA	PUFA	Calcium	Iron	Zinc	Vitamin A, RAE	Vitamin B12
	kJ (kcal)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(mg)	(mg)	(mg)	(μg)	(μg)
Beef, tenderloin steak, lean, raw[a]	566 (135)	73.0	22.2	5.1	0	1.1	1.71	1.80	0.38	14	2.48	3.37	2	3.7
Pork, tenderloin, lean, raw[a]	436 (103)	76.0	21.0	2.2	0	1.0	0.70	0.79	0.37	5	0.98	1.89	0	0.5
Beef, liver, raw[a]	546 (130)	70.8	20.4	3.6	3.9	1.3	1.23	0.48	0.47	5	4.90	4.00	4968	59.3
Pork, liver, raw[a]	542 (129)	71.1	21.4	3.7	2.4	1.4	1.17	0.52	0.87	9	23.30	5.76	6502	26.0
Mutton, shoulder, raw[d]	947 (228)	62.7	18.7	17.0	0	1.6	8.30	6.40	0.80	8	1.8	3.50	45	5
Mutton, round, raw[d]	564 (134)	71.9	20.1	6.0	0	2.0	2.90	2.30	0.30	8	2.4	3.70	45	3.0
Goat, meat, raw[c]	690 (165)	68.0	17.5	10.6	0	1.1	-	-	-	11	2.4	3.45	0	1.1
Chicken, breast, raw[a]	479 (114)	73.9	22.5	2.6	0	1.1	0.56	0.69	0.42	5	0.37	0.68	7	0.2
Turkey, breast, raw[a]	457 (108)	74.9	23.7	1.5	0	1.0	0.29	0.26	0.26	11	0.73	1.28	6	0.6
Egg, chicken, whole, raw[a]	577 (139)	76.2	12.6	9.5	0.7	1.1	3.13	3.66	1.91	56	1.75	1.29	160	0.9
Egg, ostrich, whole, raw[b]	640 (154)	75.1	12.2	11.7	0	1.4	-	-	-	65	2.5	1.34	6***	-
Milk, goat[c]	318 (76)													
Milk, cattle, whole, 3.25% milkfat[a]	256 (61)	88.1	3.2	3.3	4.8	0.7	1.87	0.81	0.20	113	0.03	0.37	46	0.5

Note: All nutrient values are expressed per 100 g edible portion on fresh weight basis (EP); SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; RAE = retinol activity equivalents. Slaughter weight and degree of maturity at slaughter weight will influence the compositions.

* Calculated using the following factors: 1 g fat = 37 kJ (9 kcal); 1 g carbohydrates = 17 kJ (4 kcal); 1 g protein = 17 kJ (4 kcal).

** Calculated as 100 - (moisture + protein + fat + dietary fibre + ash), or assumed zero for flesh meat.

*** In this case, vitamin A contents were expressed in retinol equivalents (RE).

[a] USDA–ARS, 2013 (food item ID 23374, 10060, 13325, 10110, 05062, 05219, 01123, 01211); [b] Sayed *et al.*, 1999 (food item ID 7_4317); [c] Stadlmayr *et al.*, 2012 (food item ID 07_046);
[d] Saxholt *et al.*, 2008 (food item ID 0053, 0054).

For human populations that have no access to essential n-3 fatty acids from fish (e.g. those in landlocked areas such as Mongolia), horse milk can potentially make an important contribution to meeting nutritional requirements. Horse milk has also been found to be more similar than cattle milk to human milk in terms of protein and lactose content, fatty-acid and protein profiles, and mineral content (which is fairly low); it can potentially therefore be regarded as a better food for human infants than cattle milk (Iacono *et al.*, 1992; Malacarne *et al.*, 2002, cited in Wijesinha-Bettoni and Burlingame, 2013).

Because of the confounding effects of factors such as management practices, it is more difficult to assess the influence of breed on the nutritional composition of animal-source foods than it is in the case of plant-source foods. The feed given to animals strongly influences meat, milk and egg composition, especially their fatty-acid composition (Woods and Fearon, 2009). Production system and the animal's sex and its age and weight at slaughter also affect meat composition. Milk composition is affected both by the feed eaten by the animal and by its stage of lactation. It is also affected by the number of times the animal has given birth (parity), seasonal variation and the animal's age and health. This shows that comparing findings from different studies is not straightforward, and this may be part of the reason why far fewer studies on breed-level effects on the nutrient composition of animal-source foods are available in the scientific literature than studies on effects at the cultivar and variety level in plants.

Most research on breed-level differences addresses economically significant production outcomes such as milk or meat yield, carcass composition and product quality, rather than differences in nutritional composition. However, some of the attributes investigated in such studies may be closely linked to compositional characteristics that are relevant to human nutrition. For example, intramuscular fat in meat cuts is positively associated with sensory properties such as juiciness, flavour and tenderness as perceived by consumers (Hocquette *et al.*, 2010). The fat content of muscles and the fatty-acid composition of this fat also have nutritional implications (Sevane *et al.*, 2014; Scollan *et al.*, 2014; Scollan *et al.*, 2006). Studies in various species, in both developed and developing countries, have shown the effect of breed on meat quality, both in terms of instrumental measurements (colour, water-holding capacity, collagen content, shear values, etc.) and in terms of sensorial attributes (tenderness, flavour, juiciness, etc.) (Chambaz *et al.,* 2003; Dyubele *et al.,* 2010; Jelenikova *et al.,* 2008; Li *et al.,* 2013; Muchenje *et al.,* 2008; Sanudo *et al.,*1997).

Studies of potential breed-level differences in nutrient composition have often targeted the most widespread transboundary breeds. However, a few comparative studies have evaluated locally adapted breeds (Jayansan *et al.*, 2013; Pavloski *et al*, 2013; Xie *et al.*, 2012). Breed-level data on mineral and vitamin content are scarce. Hardly any review papers or meta-analyses that provide breed-level compositional data or analyse possible differences in nutrient values have been published.

3 Filling the knowledge gap

FAO has contributed to filling the knowledge gap on biodiversity and nutrition by developing the FAO/INFOODS Food Composition Database for Biodiversity (BioFoodComp) (FAO, 2013b). The database includes data on several animal-source foods: milk from buffalo breeds and minor dairy species (273 food records, representing a total of 92 breeds) (Medhammar *et al.*, 2012); and beef (213 food records, 49 breeds) (Barnes *et al.*, 2012). Data on pork (253 food records, 110 breeds/genotypes) (Kerns *et al.,* 2015; FAO, 2015) will be added to the next version of the database. BioFoodComp has become the most comprehensive global repository of nutrient values of foods described at breed level and foods from underutilized species.

As discussed above, multiple factors influence the composition of animal-source foods and it is therefore difficult to compare compositional data from the various studies used to populate the BioFoodComp database. The protein content in milk is very stable with respect to changes in animal nutrition and feeding practices; however, the fat content and fatty-acid composition of milk are strongly affected (Walker *et al.*, 2004; Jenkins and McGuire, 2006; Laben, 1963), which complicates the interpretation of data related to these nutrients. Stage of lactation greatly influences both fat and protein content. An inverse trend to the lactation curve can generally be observed in most species, i.e. fat and protein contents are higher in early and late lactation and lower in mid lactation. Where beef is concerned, factors such as nutrition and genetics have less influence on protein content and amino acid profile, but it is recognized that micronutrient content, fat content and fatty-acid composition may be altered (Scollan *et al.*, 2006; 2014). Genetic factors generally produce smaller differences in the fatty-acid composition of meat than dietary factors (De Smet *et al.*, 2004; Shingfield, Bonnet and Scollan, 2013).

While potential confounding effects need to be borne in mind, it is interesting to note the breed-level differences in nutritional content recorded in BioFoodComp. Medhammar *et al.* (2012) report differences in milk composition for different buffalo, yak, horse and dromedary breeds. Fat and protein contents vary significantly between breeds, with differences of approximately 4 g fat and 2 g protein per 100 g milk between the highest and lowest values. Protein values for buffalo milk range from 2.7 g to 4.6 g/100 g, meaning a difference of more than 41 percent between the breeds with the highest and the lowest values. Large variations are also reported for mineral and vitamin contents. For example, calcium content is reported to differ by 73 mg/100 g between the breed with the lowest value, the Kuttanad Dwarf buffalo, and the breed with the highest value, the Egyptian buffalo. Differences between breeds, albeit smaller, are also recorded for horse milk (48 mg/100 g) and dromedary milk (15 mg/100 g). Table 1G2 presents a selection of milk-nutrient composition ranges for buffaloes, horses and dromedaries.

Data on beef and pork show between-breed differences in nutrient values for the same raw meat cut. Barnes *et al.* (2012) studied compositional data on beef from more than 30 different breeds published in BioFoodComp. Recorded fat values for the longissimus muscle range from 0.6 g to 16.0 g/100 g EP, with the lowest values reported for a Hereford–Friesian cross and highest for the Hanwoo. Value ranges for a selection of other nutrients are presented in Table 1G3. In pork, recorded fat content ranges from 0.7 g to 18.2 g fat per 100 g EP, the lowest value being from the Landrace and the highest from the Mangalitsa (Kerns *et al.,* 2015; FAO, 2015). These variations affect the saturated and mono- and polyunsaturated fatty acid contents of the meat, as well as its cholesterol content. Hardly any data on mineral and vitamin composition are available for beef or pork.

4 Potential significance for human nutrition

Animal-source foods are energy dense and are a rich source of protein, minerals, vitamins and essential fatty acids. The protein in these foods is considered to be of the highest quality because of its favourable amino-acid composition. Iron, zinc and vitamin A are the main micronutrients available in meat; calcium, vitamin B12 and riboflavin are provided in abundance by milk, which is however very low in iron. Compared to foods derived from plants, the bioavailability of these nutrients in animal-source foods is high, because of the presence of haeme-protein and the absence of phytates and fibre (Neumann *et al.*, 2002).

The roles of animal-source foods in human nutrition have been widely discussed, including their roles in alleviating undernutrition and deficiencies that lead to poor growth, impaired mental development and ill health (e.g. Dror and Allen, 2011; Neumann *et al.*, 2002; Neumann *et al.*, 2010) and their beneficial and potential negative roles with respect to diet-related non-communicable diseases (e.g. Weaver *et al.*, 2013; Givens, 2010; McAfee *et al.*, 2010).

TABLE 1G2

Selected nutrient composition ranges for milk from buffalo, horse and dromedary breeds

	Average ± SD	Range	Breed with lowest value	Breed with highest value
Buffalo-milk composition (values per 100 g milk)				
Protein (g)	4.0 ± 0.5 n = 42	2.7–4.6	Non-descript hill buffalo (Kumaon region, India)	Mediterranean
Fat (g)	7.4 ± 0.9 n = 75	5.3–9.0	Bulgarian x Murrah breed (Bulgaria)	Bhadawari
Lactose (g)	4.4 ± 0.6 n = 23	3.2–4.9	Kuttanad Dwarf (Kerala, India)	Bulgarian Murrah
Calcium (mg)	191 ± 38 n = 9	147–220	Kuttanad Dwarf (Kerala, India)	Egyptian
Magnesium (g)	12 ± 5 n = 6	2–16	Kuttanad Dwarf (Kerala, India)	Murrah (Bombay, India; France)
Horse-milk composition (values per 100 g milk)				
Protein (g)	2.0 ± 0.4 n = 33	1.4–3.2	Sana, “mtsyri”	Palomino
Fat (g)	1.6 ± 0.7 n = 45	0.5–4.2	Lusitano	Saddle pony
Lactose (g)	6.6 ± 0.4 n = 31	5.6–7.2	Buryat	Trotters
Calcium (mg)	95 ± 19 n = 26	76–124	Thoroughbred	Palomino
Magnesium (mg)	7 ± 2 n = 18	4-12	Lusitano	Palomino
Zinc (mg)	0.2 ± 0.1 n = 8	0.2-0.3	Shetland	Italian saddle horse
Vitamin C (mg)	4.3 ± 3.3 n = 6	1.7–8.1	Saddle pony	Palomino
Dromedary-milk composition (values per 100 g milk)				
Protein (g)	3.1 ± 0.5 n = 12	2.4–4.2	Kachchhi	Wadah
Fat (g)	3.2 ± 1.1 n = 23	2.0–6.0	Kachchhi	Arvana
Lactose (g)	4.3 ± 0.4 n = 15	3.5-4.9	Arvana	Hamra
Calcium (mg)	114 ± 6 n = 5	105–120	Arvana	Majaheem
Magnesium (mg)	13 ± 1 n = 4	12-14	Hamra	Najdi
Zinc (mg)	0.6 ± 0.1 n = 4	0.4-0.6	Najdi	Majaheem
Vitamin C (mg)	6.7 ± 7 n = 5	2.5–18.4	Majaheem	Arvana

Note: Locations, where listed, indicate the places of origin of the animals from which milk samples were taken for analysis.
n = number of total data points (where data for the same dairy breed were available from more than one study, the mean value for the breed was calculated and used; n represents the number of data points before averaging for breed). Composition is affected by management factors as well as by genetics (see main text for further discussion).
Source: Adapted from Medhammar *et al.*, 2012.

TABLE 1G3

Selected nutrient composition ranges for beef (longissimus muscle) from different cattle breeds

Nutrients	Average ± SD	Range	Breed with lowest value	Breed with highest value
Protein (g)	21.8 ± 1.1 n = 64	18.6–25.7	Brown Swiss (Spain)	Criollo Argentino (Argentina)
Fat (g)	3.2 ± 2.7 n = 123	0.6–16	Hereford–Friesian cross (New Zealand)	Hanwoo (Republic of Korea)
Cholesterol (mg)	48 ± 9 n = 22	36–68	Bonsmara (South Africa)	Aberdeen Angus (Czech Republic)
SFA (g)	1.54 ± 1.69 n = 63	0.14–8.39	Austriana Valles (Spain)	Hanwoo (Republic of Korea)
MUFA (g)	1.36 ± 1.27 n = 62	0.10–5.92	Austriana Valles (Spain)	Hanwoo (Republic of Korea)
PUFA (g)	0.26 ± 0.23 n = 58	0.08–1.46	Criollo Argentino (Argentina)	Charolais × Angus (Argentina)
FA C14:0 (g)	0.08 ± 0.01 n = 86	0.01–0.60	Austriana Valles (Spain)	Hanwoo (Republic of Korea)
FA C18:2 n-6 (LA) (g)	0.13 ± 0.10 n = 47	0.02–0.43	Bonsmara (South Africa)	Aberdeen Angus (Czech Republic)
FA C20:5 n-3 (EPA) (g)	0.01 ± 0.01 n = 46	<0.01–0.04	Tudanca (Spain)	Barrosa (Portugal)

Note: Values per 100 g edible portion on fresh weight basis; n = number of total data points (nutrient values of same breeds have not been averaged); FA = fatty acid; SFA = saturated fatty acids; MUFA = monounsaturated fatty acids; PUFA = polyunsaturated fatty acids; LA = linoleic acid; EPA = eicosapentaenoic acid. Locations indicate the places of origin of the animals from which meat samples were taken for analysis. Composition is affected by management factors as well as by genetics (see main text for further discussion).
Sources: Barnes *et al*., 2012; FAO, 2013b.

Dietary fat receives a lot of attention with regard to its roles in the epidemiology of non-communicable diseases such as cardiovascular pathologies, cancer and type-2 diabetes (e.g. WHO/FAO, 2003; FAO, 2010). These diseases are becoming more common in both developed and developing countries (WHO/FAO, 2003). Emphasis has been placed on reducing the intake of total fat, saturated fatty acids (SFA – considered to be associated with increased LDL-cholesterol) and increasing the intake of n-3 polyunsaturated fatty acids (PUFA – recognized to be protective against cardiovascular diseases and to play a beneficial role in terms of promoting general health). Dietary recommendations have been published for fatty-acid classes as well as for specific fatty acids (FAO, 2010).

Meat plays an important role in the diet of many populations, and although the general contribution of meat to fat supply in the human diet is low (less than 20 percent) (Culioli *et al.*, 2003), identifying breeds whose products have beneficial fatty-acid profiles has the potential to contribute to healthier diets (e.g. Sevane *et al.*, 2014). A comparison of beef from three breeds (Cuvelier *et al.*, 2006) showed large between-breed differences in SFA content: Belgian Blue, Limousin and Aberdeen Angus, respectively, provided 2.2 percent, 6.2 percent and 9.2 percent of the recommended SFA intake. Large differences in n-3 PUFA content between these breeds were also reported.

In low-input systems, cross-breeding with exotic breeds can potentially lead to lower nutrient densities in milk, with potential consequences for human nutrition. Mapekula *et al.* (2011) report an instance of this effect in dairy cattle grazed on rangeland in South Africa and note that it may be related to the cross-bred animals having a lower capacity to convert poor-quality feed into milk protein.

Micronutrient malnutrition (i.e. vitamin and mineral nutritional deficiency) is very prevalent in developing countries. Milk is considered to be an important source of zinc for children at risk of micronutrient deficiencies (Neumann *et al.*, 2002). Two cups (500 ml) of milk per day provide 24 to 72 percent of the recommended nutrient intake (RNI) of zinc for children in the one-year to three-year age group, depending on the species of the dairy animal (Table 1G4). Between-breed differences can be almost as large as those between species. For example, according to the figures presented in Table 1G2, two cups of milk from the Najdi breed of dromedary provide less than 50 percent of the zinc RNI per day for children in this age group, while the equivalent amount from the Majaheem breed provides more than 70 percent.

Findings on the vitamin C content of horse and dromedary milk are also interesting: while two cups of milk from the breeds whose milk has the lowest reported vitamin C content supply less than 50 percent of the RNI for children aged one to three years, the equivalent amount of milk from the breeds whose milk has the highest vitamin C content exceeds the RNI, with milk from the Palomino horse supplying 132 percent of the RNI and milk from the Arvana dromedary supplying 301 percent. The large amount of vitamin C in dromedary milk is recognized as being important in desert areas, where vegetables and fruits are scarce (Barłowska *et al.*, 2011). Cattle milk, in contrast, is reported to be low in vitamin C.

5 Research priorities

The composition of animal-source foods is influenced by a number of different factors. Some comparative studies that assess the effect of breed *per se* and identify nutritional differences by controlling for other factors have been undertaken. However, high-quality studies are lacking, i.e. studies that include all the necessary information on confounding factors and analytical methods used and, preferably, have a control group for comparison. Meta-analyses that enable sound conclusions to be drawn from results obtained in different studies are needed. There is also a need to expand the range of species and breeds targeted by nutritional composition studies. Studies often focus on a narrow range of nutrients that influence product quality. Research needs to target a wider range of nutrients of public-health concern, including studies on amino-acid composition and protein digestibility. Data on vitamin and mineral contents are particularly needed.

TABLE 1G4

Mineral content of milk from various species in relation to recommended nutrient intake

Minerals	RNI for children aged 1–3 years Breed with lowest value	Buffalo		Horse		Dromedary		Cattle
		Breed with lowest value	Breed with highest value	Breed with lowest value	Breed with highest value	Breed with lowest value	Breed with highest value	Average value
Calcium (mg)	500	✓✓	✓✓	✓	✓✓	✓✓	✓✓	✓✓
Magnesium (mg)	60		✓✓		✓	✓	✓✓	✓
Zinc (mg)	4.1	n/a	n/a				✓	
Vitamin C (mg)	30	n/a	n/a		✓✓		✓✓	

Note: RNI = recommended nutrient intake values for children aged 1-3 years (FAO, 2002).
✓✓ = 100% of RNI supplied by 2 cups (500 ml) of milk; ✓ = 70–99% of RNI supplied by 2 cups (500 ml) of milk; empty cells = less than 70% of RNI supplied by 2 cups (500 ml) of milk; n/a = data unavailable.
Sources: RNI supply for buffalo, horse and dromedary milk is calculated using the nutrient values presented in Table 1G2. Cattle data are from USDA–ARS, 2013.

Given that there is evidence that breed influences the composition of animal-source foods, there is a need to:

- obtain data on different breeds and their production environments, so as to be able to disentangle genetic and environmental factors;
- generate, compile and disseminate more compositional data on animal-source foods from different breeds, especially locally adapted breeds;
- further investigate evidence for the significance of species- and breed-level differences to human health by developing meta-analysis approaches and strategies for avoiding confounding effects (such as differences in nutritional habits other than consumption of meat and dairy products); and
- take information on the composition of animal-source foods into account in nutrition and agricultural policies and programmes.

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