## 

# Supplementary material – methodology

## Carcase products and raw weights

The raw weight of a ‘typical’ Australian lamb carcase was based on primal cuts from the Handbook of Australian Meat (HAM) (AUSMEAT, 2020). The HAM is a book that describes Australian beef and sheep meat cuts and co-products to enable both meat importers and exporters to communicate using a common language. Primal cuts (initial cuts of meat from the carcase) were chosen to optimize recovery and to eliminate variation in weight that arises from butchering the carcase into retail cuts (*Table 1*).

All the primal cuts have the same Central Product Classification (CPC) of 21115 (Department of Economic and Social Affairs, 2015). The CPC is an international standard published by the United Nations that classifies all goods and services to facilitate data collation and statistical analysis of production, trade and consumption of goods, at both the national and international level (Department of Economic and Social Affairs, 2015).

(*Table 1*).

*Table 1: Carcase primal cuts included in the "typical" Australian lamb carcase model with corresponding HAM and CPC numbers*

|  |  |  |
| --- | --- | --- |
| **Primal cut** | **HAM number** | **CPC number** |
| Neck | 5020 | 21115 |
| Square cut shoulder | 4990 |
| Fore shank | 5030 |
| Breast | 5010 |
| Rack | 4930 |
| Short loin | 4880 |
| Flap | 5010 |
| Chump – bone in | 4790 |
| Leg, chump off, bone - in | 4830 |
| Hind shank | 5031 |

References: HAM (AUSMEAT, 2020); CPC (Department of Economic and Social Affairs, 2015)

Raw weights of the primal cuts and secondary carcase products were calculated using the Lamb Value Calculator MkII (LVC) (Smith, 2019). This was a two-step process. Step one was to describe the carcase (Table 2) and step two was to describe the primal cuts (Table3). The LVC is an Excel ® based program that uses current grading inputs to predict the weight of commercial cuts as specified by the user (Meat and Livestock Australia, 2021).

*Table 2: Carcase specifications for the "typical" Australian lamb selected from the LVC*

|  |  |
| --- | --- |
| **Lamb Value Calculator MkII parameter** | **Setting chosen for developing the “typical” Australian Lamb** |
| Yield model | CCW/GR |
| Shrinkage | 1% |
| Breed | Cross breed |
| Average GR fat depth | 8 mm |
| Fat score | FS2 |
| Average HSCW | 22 kg |

Reference: Lamb Value Calculator Mk II (Smith, 2019).

Breed, average GR fat depth, fat score and average HSCW were set based on the preferred market specifications for Australian supermarket lamb (Meat and Livestock Australia, 2020). Shrinkage was set to minimize loss from this pathway and was based on research by Treffone and McPhail’s (2011).

*Table 3: Primal cut descriptions and weights as selected in the LVC*

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Region** | **Primal cut type** | **Options** | **Cut description** | **Raw weight (kg)** |
| Forequarter | Shoulder | Square cut | Fat cap 6mm, angle cut (4 rib) | 5.17 |
| Forequarter | Fore shank | Fore shank | Tipped | 0.80 |
| Forequarter | Breast | Breast | Breast | 0.44 |
| Forequarter | Neck | Neck | Angle cut | 0.0.80 |
| Loin | Short loin | Short loin | Short loin cap 25 mm tail, 6 mm fat cap | 1.66 |
| Loin | Rack | Cap on | Rack, 8 x 100 mm rib, 6 mm fat, cap on | 2.20 |
| Loin | Flap | Flap | Flap | 2.18 |
| Hindquarter | Leg | Chump off | Leg Chump Off, Bone in, Shank off, 6mm Fat Cap | 4.43 |
| Chump, bone in, 6 mm | 1.41 |
| Hind shank (tipped) | 0.95 |

Reference: Lamb value calculator MkII (Smith, 2019).

The fat cap was set at 6 mm as this is the preference for the domestic market (Williams & Droulez, 2010). Bone-in options were selected to optimize the recovery of edible product from the carcase.. We assumed the shanks in the Australian food composition database were tipped(Food Standards Australia New Zealand, 2019),

## Co-products (edible offal and non-carcase fat) and raw weights

The co-products included in the lamb model for nutrient distribution were based on those listed in the Lamb Yield Guide (Agriculture and Horticulture Development Board, 2020) and the HAM (AUSMEAT, 2020).

Edible offal pieces are referred to as “fancy meats” in the HAM, a type of co-product. The HAM does not include pancreas, intestines or visceral fat. The CPC aggregated edible sheep offal to one category; it has the product number 21155 (Table 4).

Body fat, trimmed from the carcase, is as categorised as a “variety item” in the HAM, a type of co-product (AUSMEAT, 2020). Unrendered sheep fat has a designated CPC number, 21514 and includes body fat and visceral fat (Department of Economic and Social Affairs, 2015).

The HAM does not include pancreas or visceral fat.

The model of the ‘typical’ Australian lamb did not include intestines, head meat, tendons (feet) or trachea due to insufficient data (weight, edible conversion factor and/or nutrient composition). The HAM does not include intestines.

*Table 4: edible sheep offal and slaughter fat included in the "typical" Australian lamb carcase model with corresponding HAM and CPC numbers*

|  |  |  |
| --- | --- | --- |
| **Co-product** | **HAM number** | **CPC number** |
| Liver | 7030 | 21155 |
| Kidney | 7040 |
| Heart | 7050 |
| Tongue | 7000 |
| Spleen | 7090 |
| Brain | 7070 |
| Lungs | 7100 |
| Pancreas | Not included in the HAM |
| Thymus | 7060 |
| Tripe | 7080 |
| Body fat | 7499H | 21514 |
| Visceral fat | Not included in the HAM |

Where available, Australian offal weights were used, with the most recently published data selected to create the “typical” Australian lamb model. Weights for liver, kidneys, heart, spleen and tripe were taken from “Best practice offal collection” (Sentance, 2011). These raw weights were a mix of lamb and adult sheep offal, collected and weighed in the abattoir where the animals were slaughtered. Between 30-70 individual pieces of each type of offal were weighed on 22 August 2007 and the average weight for each offal type calculated.

Weight for tongue was taken from “By-product yields for sheep and cattle” (Spooncer, 1992). This was the average weight of short cut tongues from 20 lambs with an average carcase weight of 18.4 kg and fat score of 1-3.

Weight for the brain was taken from “Composition of Australian foods. 36. Beef, lamb and veal offal” (Hutchison et al., 1987). This is the average weight of nine lambs’ brains “purchased” at the retail level in Sydney in 1985. A purchase was defined as either “2 each of the large items or 1-2 kg of the small items” with no clarification of which offal pieces were considered small and which pieces were considered as large.

Where data from Australian sheep were not available, co-product weight values were taken from overseas. Data was sort from countries that have similar sheep production systems to Australia, noting the variation in nutrient composition data for the same product that exists between these countries (de Bruyn et al., 2016). The weight for lungs and thymus were taken from McCutcheon, Blair and Purchas (1993). This was the average weight of these offal pieces sourced from 13 New Zealand Romney rams that were part of a university research flock. The rams were slaughtered at 16 - months of age and had a carcase weight of 22.5 kg and a GR tissue depth of 6.2 mm. Weight of pancreas and non-carcase fat was taken from the UK Lamb Yield Guide (Agriculture and Horticulture Development Board, 2020). This guide is published in the grey literature and is based on offal yields from an average UK lamb with carcase weight of 21.1 kg with average fatness of R3L.

*Table 5: Lamb offal weights used in the model of the typical Australian lamb*

|  |  |
| --- | --- |
| **Offal piece** | **Raw weight (kg)** |
| Liver | 0.707 |
| Kidneys (x2) | 0.149 |
| Heart | 0.251 |
| Tongue | 0.0955 |
| Spleen | 0.112 |
| Brain | 0.093 |
| Lungs | 0.4489 |
| Pancreas | 0.11 |
| Thymus | 0.0415 |
| Tripe | 0.57 |
| Body fat | 0.68 |
| Visceral fat | 1.89 |

References: Sentance (2011), Spooncer (1992), Agriculture and Horticulture Development Board (2020), Smith (2019)

The data for offal weights in all the studies were based on 9-70 samples. McCutcheon, Blair and Purchas (1993) were the only authors to include all key pieces of metadata i.e., age/sex/body condition score of the animals that were the source of the offal. Sheep offal weights are known to vary according to sex, age and body condition score (Riley et al., 1989; Spooncer, 1978) introducing uncertainty in the offal raw weight. This is compounded by the low sampling numbers and together these factors are likely to introduce significant sampling error, as highlighted by Sentence (2011).

For the remainder of this paper, carcase products refers to the primal carcase cuts (neck, square cut shoulder, fore shank, breast, rack, short loin, flap, chump – bone in, leg – chump off, bone in, hind shank). “Red offal” refers to tongue, heart, liver, kidneys (2) and spleen. “White offal” refers to brain, lungs, thymus, pancreas and tripe. Slaughter fat refers to body fat (derived from the carcase) and visceral fat (kidney fat and omentum). Co-products refers to red offal, white offal and slaughter fat.

## Edible portions of carcase products and co-products

The authors were unable to find published data on the edible to inedible ratio of lamb carcase primals. As a substitute, edible to inedible ratios were taken from retail cuts available in the Australian Food Composition Database (AFCD) (Food Standards Australia New Zealand, 2019), except for breast and flap. Retail cuts were selected that are derived from the primals and that had the smallest disparity in bone percentage when compared with the in the LVC. The neck primal cut had no equivalent retail cut in the AFCD, so the nearest anatomical cut was used, the forequarter chop. There was no distinction in the AFCD between foreshanks and hind shanks. This approach was taken as the gross composition data in the ACFD comes from analysed data in Williams et al. (2006), reducing uncertainty compared with using the modelled data from the LVC. The current AFCD does not contain gross composition data on lamb breast and flap. The edible to inedible ratio for these cuts was taken from the LVC (Smith, 2019) by subtracting the bone weight from the primal weight.

Offal edible portions for liver, kidneys, heart, tongue and brain were taken from “Composition of Australian foods. 36. Beef, lamb and veal offal” (Hutchison et al., 1987) (Table6). This data comes from a cross-sectional study that collected samples at the retail stage and analysed the amount of edible and inedible product for each offal piece. Edible portions for pancreas, lugs and spleen were taken the Canadian Nutrient File (Government of Canada, 2015). This source of the data is predominantly the US Department of Agriculture (USDA) (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2019). The USDA data is historical and is no longer being updated. These data were originally available in the USDA National Nutrient Database and based on Standard Reference. Thymus and tripe edible portions were taken from the Composition of foods integrated dataset (Public Health England, 2019). The data is more than 25 years old and based on 12 or fewer samples.

The edible component of body fat was taken from the AFCD (Food Standards Australia New Zealand, 2019). Published information on the edible portion of visceral fat was not found, so the authors imputed the edible portion factor from carcase fat, using the AFCD (Food Standards Australia New Zealand, 2019).

*Table 6: Edible portion of carcase products and co-products in the model 'typical' Australian lamb*

| **Product** | **Retail cut** | **Source and Public food identification** | **Edible portion** |
| --- | --- | --- | --- |
| Neck | |  | | --- | | Lamb, forequarter chop, untrimmed, raw | | AFCD  F004888 | 0.775 |
| Square cut shoulder | |  | | --- | | Lamb, forequarter chop, untrimmed, raw | | AFCD  F004888 | 0.775 |
| Fore shank | Lamb, shank, untrimmed, raw | AFCD  F005143 | 0.875 |
| Breast | Not applicable | Smith | 0.591 |
| Rack | Lamb, frenched cutlet/rack, untrimmed, raw | AFCD  F004923 | 0.708 |
| Short loin | Lamb, loin chop, untrimmed, raw | AFCD  F005044 | 0.837 |
| Flap | Not applicable | Smith | 0.708 |
| Chump- bone in | Lamb, chump chop, untrimmed, raw | AFCD  F004911 | 0.868 |
| Leg, chump off, bone-in | Lamb, leg roast, untrimmed, raw | AFCD  F005017 | 0.766 |
| Hind shank | Lamb, shank, untrimmed, raw | AFCD  F005143 | 0.875 |
| Tongue | Not applicable | Hutchison et al. | 0.980 |
| Heart | Not applicable | Hutchison et al. | 0.730 |
| Liver | Not applicable | Hutchison et al. | 1.000 |
| Kidney (x2) | Not applicable | Hutchison et al. | 0.900 |
| Spleen | Lamb, spleen, raw | CNF  3629 | 1.000 |
| Brain | Not applicable | Hutchison et al. | 0.930 |
| Lungs | Lamb, lungs, raw | CNF  3620 | 0.760 |
| Pancreas | Lamb, pancreas, raw | CNF  3625 | 1.000 |
| Thymus | Sweetbread, lamb, raw | CoFID  174446 | 1.000 |
| Tripe | Tripe, dressed, raw | CoFID  18-428 | 1.000 |
| Body fat | Lamb, all cuts, separable fat, raw | AFCD  F004831 | 1.000 |
| Visceral fat | Lamb, all cuts, separable fat, raw | AFCD  F004831 | 1.000 |

References: Food Standards Australia New Zealand (2019); Hutchison et al. (1987); Smith (2019); Government of Canada (2015); (Public Health England, 2019)

AFCD – Australian food composition database

CNF – Canadian nutrient file

CoFID – Composition of foods integrated database

## Nutrient composition data

Nutrient composition of primal cuts was calculated using data at the retail cut level, as for the edible portion. As there is no known published data for the nutrient composition of Australian lamb neck, breast or flank, forequarter chop data was imputed for the neck and the breast and flap data were imputed with diced lamb data.

Nutrient composition data for carcase primal cuts, a range of offal pieces (tongue, heart, liver, kidney, and brain) and body fat were taken from “AUSNUT 2011-2013” (Food Standards Australia New Zealand, 2014). Visceral fat nutrient composition data were imputed from separable, carcase fat data in the AUSNUT 2011-2013. Nutrient data for spleen, lungs and pancreas were taken from the Canadian Nutrient Files (Government of Canada, 2015). The majority of nutrients for thymus were taken from the SR Legacy dataset, with niacin dietary equivalents, vitamin B6 and dietary folate equivalents coming from the UK CoFID. Nutrient composition data for tripe were also sourced from UK CoFID, with selenium being imputed from beef tripe from the SR Legacy dataset (Public Health England, 2019; U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2019) (Table7).

Head meat, feet/tendons, trachea, omasum, abomasum and intestines were not included in the model typical Australian lamb due to insufficient weight data, edible conversion factor and/or nutrient composition data.

All carcase products and co-products were considered as raw and untrimmed to minimise variation created by cooking method and preparation and reflect the state of the edible products at the end of processing at the abattoir.

*Table 7: retail cuts used to calculate nutrient composition of carcase primal cuts and offal pieces of a 'typical' Australian lamb*

|  |  |  |
| --- | --- | --- |
| **Carcase product/co-product** | **Retail cut** | **Source and food ID** |
| Neck | |  | | --- | | Lamb, forequarter chop, untrimmed, raw | | AUSNUT 2011-13  08A20700 |
| Square cut shoulder | |  | | --- | | Lamb, forequarter chop, untrimmed, raw | | AUSNUT 2011-13  08A20700 |
| Fore shank | Lamb, shank, untrimmed, raw | AUSNUT 2011-13  08A20679 |
| Breast | Lamb, diced, untrimmed, raw | AUSNUT 2011-13  08A20673 |
| Rack | Lamb, frenched cutlet/rack, untrimmed, raw | AUSNUT 2011-13  08A20707 |
| Short loin | Lamb, loin chop, untrimmed, raw | AUSNUT 2011-13  08A20721 |
| Flap | Lamb, diced, untrimmed, raw | AUSNUT 2011-13  08A20673 |
| Chump- bone in | Lamb, chump chop, untrimmed, raw | AUSNUT 2011-13  08A20667 |
| Leg, chump off, bone-in | Lamb, leg roast, untrimmed, raw | AUSNUT 2011-13  08A20714 |
| Hind shank | Lamb, shank, untrimmed, raw | AUSNUT 2011-13  08A20679 |
|  |  |  |
| Tongue | Lamb, tongue, raw | AUSNUT 2011-13  08D10183 |
| Heart | Lamb, heart, raw | AUSNUT 2011-13  08D10179 |
| Liver | Lamb, liver, raw | AUSNUT 2011-13  08D10185 |
| Kidney (x2) | Lamb, kidney, raw | 08D10181 |
| Spleen | Lamb, spleen, raw | CNF  3629 |
| Brain | Lamb, brain, raw | AUSNUT 2011-13  08D10177 |
| Lungs | Lamb, lungs, raw | CNF  3620 |
| Pancreas | Lamb, pancreas, raw | CNF  3625 |
| Thymus | Lamb, New Zealand, imported, sweetbread, raw and,  Sweetbread, lamb, raw | SR Legacy and CoFID  174446 and  18-421 |
| Tripe | Tripe, dressed, raw and,  Beef, variety meats and by-products, tripe, raw | CoFID and SR Legacy  18-428 and 13341 |
| Body fat | Lamb, all cuts, separable fat, raw | AUSNUT 2011-13  08A20749 |
| Visceral fat | Lamb, all cuts, separable fat, raw | AUSNUT 2011-13  08A20749 |

References: AUSNUT 2011-13 Australian food composition database (Food Standards Australia New Zealand, 2014), The Canadian nutrient file (CNF), Composition of Foods Integrated Dataset (CoFID) (Public Health England, 2019) and Standard Reference Legacy Foods Database (U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2019)

Regarding selection of nutrients to include in the model, to begin with all nutrients and energy from the AUSNUT 2011-13 Australian Food Composition Database (Food Standards Australia New Zealand, 2014) were included except dietary fibre, carbohydrates, alcohol and caffeine due to the negligible levels of these nutrients in the food products of interest. Where multiple forms of a nutrient were included, the aggregated nutrient form was included. Micronutrients were then excluded where a single serve of any product did not provide at least 10% of the recommended daily intake (for Australian men and women of reproductive age). This resulted in calcium and iodine being excluded from the model. Vitamin E and fatty acids were removed from the model due to a lack of information on these nutrients in the overseas food composition databases. (*Table* ***8***).

*Table 8: macro- and micro-nutrients included in the case study examining nutrient distribution across a 'typical' Australian lamb*

|  |  |  |  |
| --- | --- | --- | --- |
| Macronutrients | Vitamins | Minerals | Fats, fatty acids, and others |
| Energy (kJ) | Vitamin A retinol equivalents (μg) | Iron (mg) | Cholesterol (mg) |
| Moisture (g) | Thiamine (B1) (mg) | Magnesium (mg) | Tryptophan (mg) |
| Protein (g) | Riboflavin (B2) (mg) | Phosphorus (mg) | Total saturated fat (g) |
| Total fat (g) | Niacin (B3) (mg) | Selenium (mg) | Total monounsaturated fat (g) |
| Ash (g) | Dietary folate equivalents (µg) | Sodium (mg) | Total polyunsaturated fat (g) |
| Vitamin B6 (mg) | Zinc (mg) |
| Vitamin B12 ( µg) |  |

The majority of nutrient composition data in the AUSNUT 2011-13 comes from two sources – Williams et al. (2007) carcase products and Hutchison et al. (1987) for the offal pieces. In both these studies sample numbers ranged from 4-11 for each cut/piece. The samples were all collected at the retail level with limited metadata of the source animals (lamb being the sole piece of metadata available). Both studies were cross-sectional. For the majority of nutrients, test results are based on one composite sample for each offal piece; for the carcase products some of the cuts were aggregated further (e.g., chump chops, leg roast, easy carve leg roast and mini roast) and then one composite sample was nutrient tested. Data from the Canadian Nutrient Files is sourced from the SR Legacy database predominantly, an historic database that is no longer being updated (Government of Canada, 2015; U.S. Department of Agriculture and U.S. Department of Health and Human Services, 2019).

## Edible weights and nutrients

The edible weight of each raw, untrimmed primal cut, edible offal piece and slaughter fat type was then calculated and the ratio of the edible weight of each edible portion to the total available edible weight was calculated. The nutrient and energy content of each edible portion was then calculated and summed to estimate the total nutrient and energy content of all the edible portions in the model ‘typical’ Australian lamb. The relative nutrient contribution of each carcase product and co-product was then calculated.

Uncertainties in the input data were qualitatively assessed and an overall average level of uncertainty of the nutrient distribution was estimated.

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