The effects of thermal processing of beef for institutional food service purposes

Ladislav Staruch, Marcel Mati

Department of Food Science and Technology
Faculty of Chemical and Food Technology
Slovak University of Technology in Bratislava
Bratislava, Slovak Republic

Abstract

Beef is sometimes referred to as the "meat of the rich", and there is some historical justification for this. Beef consumption can to some extent be considered an indicator of the purchasing power of the population. Since 1995, beef consumption in Europe has slumped by approximately 11%. Another significant fall of around 5% was caused by the BSE scare. Its impact was not, however, as dramatic as that seen in the early 1990s when BSE incidence reached its peak. Thanks to special sanitation measures and market reorganisation, beef consumption increased again to reach almost the same levels recorded before BSE first appeared (Sarzeaud et al. 2008). The extensive study presented here endeavours to fill in the gaps in the research and scientific data in this area by providing information on the chemical composition of thermally processed beef.

Beef, cooking, stewing, roasting and frying, chemical composition, obesity

Introduction

Consumption of beef in the past and present

Current consumption of beef in Slovakia is about 4 kg per person per year (Table 1). The consumption of different types of meat in kg per person between 2006 and 2010 is shown in Fig. 1. These levels of beef consumption represent less than 24% of the recommended consumption of 17.5 kg per person per year. A comparison between Slovakia and Denmark is also interesting. Although Denmark is comparable to Slovakia in population, its beef consumption is almost 85% higher than that of Slovakia. This is because Slovakia (along with Hungary) is one of the European Union countries with the lowest beef consumption. Moreover, the consumption of beef is less than its consumption of any other type of meat. However, thanks to its composition, beef deserves a greater role in the population's nutrition. This can also be promoted by institutional food service facilities. Beef could be offered as a regular item on the menu in school cafeterias, and children could learn

Table 1. Consumption of individual types of meat in selected countries in kg/person/year in 2009 (Eurostat 2012; Czech Statistical Office 2012; USDA 2012)

Country	Beef and veal	Pork	Poultry
Czech Republic	10.0	41.0	25.0
Denmark	26.0	80.0	26.0
France*	25.0	33.0	23.0
Hungary	3.0	44.0	29.0
Germany	13.0	54.0	19.0
Austria	18.0	57.0	20.0
Slovak Republic	4.0	31.0	20.0
USA	59.0	47.0	56.0
Recommended consumption	17.5	22.0	15.0

*largest EU member state

Address for correspondence:
Ing. Ladislav Staruch, PhD.
Department of Food Science and Technology
Faculty of Chemical and Food Technology
Slovak University of Technology in Bratislava
Radlinského 9, 812 37 Bratislava 1, Slovak Republic

Phone, fax: +421 259 325 451
E-mail: ladislav.staruch@stuba.sk
www.maso-international.cz

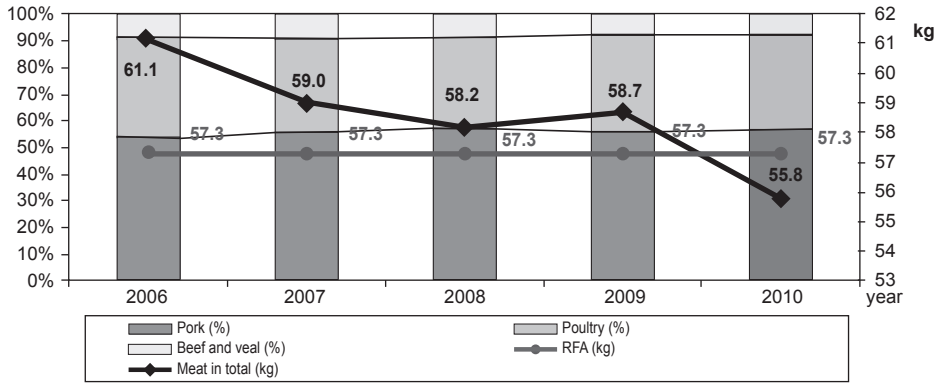

Fig. 1. Meat consumption in the Slovak Republic in kg per person (Sitárová 2010)

about and get a better understanding of the nutritional status of beef thanks to its greater promotion. A fundamental aspect of this is the culinary and gastronomic preparation of beef.

Food service in schools and the programme for a healthier diet for the population

Food service operations are an essential part of social programmes in developed countries. They need to be given particular attention, from food services for pre-school and school institutions to food services in companies and for senior citizens.

Food service facilities are obliged to follow nutritional recommendations that provide information about the amounts of individual nutrients needed and their proportions in the diet.

One significant problem that may result from unhealthy dietary habits is obesity, which does not affect only the USA (which is frequently mentioned in this connection), but is also becoming an increasingly topical issue in Europe. Thirty to eighty per cent of the adult population in Europe are overweight (BMI greater than 25) and more than one third of adult population in the region suffers from obesity (BMI in excess of 30). About 20% of children are overweight and about a one third suffer from obesity. Obesity was found in 17.6% of Slovak men, while the incidence of obesity was 25.1% among Slovak women (The Public Health Authority of the Slovak Republic 2012).

A 17.3% of men and a 17.5 % of women were identified as obese in the Czech Republic (The National Institute of Public Health of the Czech Republic 2011).

The Slovak Republic is endeavouring to reduce the negative effects of unhealthy lifestyles in general and an unhealthy diet in particular, and has launched a Programme for a Healthier Diet for the Population of the Slovak Republic. The most important reason for the development and implementation of this programme was the fact that the diet consumed by the Slovak population has, for many years, been characterised by an energy excess and been unbalanced with respect to nutrients and the protective factors they contain. This results in a high-risk situation from the viewpoint of the incidence of diseases that are non-infectious in nature, particularly cardiovascular and oncological diseases, obesity and diabetes (Rovný 2008).

One obesity prevention strategy may be to reduce the consumption of meat (or meat cuts) with elevated concentrations of cholesterolemic fatty acids, such as palmitic fatty acid, and to consume meat that contains less cholesterolemic fatty acids and more of the fatty acids that are not considered cholesterolemic, such as oleic and stearic acid, instead. Beef

contains up to 50% non-cholesterolemic fatty acids (oleic acid, stearic acid) and around 20% palmitic acid. For this reason beef is, from the nutritional viewpoint, preferable to pork, which has a different fatty acid ratio.

Materials and Methods

Three categories of beef purchased in a retail outlet were used in the experiment. These were basic types of beef, i.e. muscle tissue, muscle tissue containing fat tissue and muscle tissue containing connective tissue.

a/ Lean beef (LB), divided into 3 subgroups:
- LB I – beef leg and beef loin muscles
- LB II – beef loin muscle
- LB III – beef leg muscle

b/ High-fat beef (HFB) consisting of short plate and flank meat, divided into 3 subgroups identified as I, II and III, similarly to lean beef.

c/ Beef foreshank (BFS), also divided into 3 subgroups and designated as I, II and III.

The above types of beef were subjected to various forms of thermal processing, i.e. boiling, stewing, roasting and frying. Lean beef was tested using all of the above forms of thermal treatment, while high-fat beef and foreshank were only boiled and stewed. The quantities of meat, water and oil used correspond to the serving portions stipulated by school food service guidelines. We used no spices or salt during thermal processing. The meat was cut into cubes for boiling or stewing, and cut into slices for roasting and frying. All thermal processing except frying was performed in enamel pots with lids.

Thermal processes:

Boiling – cooking in water heated to boiling point.
Roasting – usually performed in an oven where heat is transferred through natural or forced air convection and applied to the meat from all sides.
Stewing – a very gentle form of cooking used mainly for meat and vegetables. Stewing causes only minimal losses of primary and secondary nutrients (Hlásná 2008).
Frying – the cooking of foods in hot fat (Decree 981/1996-100 of the MoI and MoH of the SR).

A total of 42 samples were prepared for analysis:
18 samples of lean beef (raw, boiled, broth, stewed with juice, roasted with juice, fried)
12 samples of high-fat beef (raw, boiled, broth, stewed with juice)
12 samples of beef foreshank (raw, boiled, broth, stewed with juice)
We determined the following basic parameters in individual samples:
- water and dry matter (3 parallel measurements)
- total lipids (2 parallel measurements)
- proteins (3 parallel measurements)
- ash (2 parallel measurements)

Water and dry matter – drying homogenised samples with sand to a constant weight loss at 105 °C (Dubravický 1989).
Total lipids – extraction of dried samples in a Twisselman extractor using petroleum ether, followed by gravimetric extraction (Dubravický 1989).
Proteins – using the Kjeldahl method to determine total nitrogen, multiplied by a factor of 6.25 (Dubravický 1989).
Ash – ashing of dried samples in a muffle furnace at 550 °C (Dubravický 1989).
The results of the experiments were processed and mathematically and statistically evaluated using the following characteristics (Eckschlager 1980):

a/ arithmetic mean ($\overline{X}$)

$$\overline{X} = \frac{\sum_{i=1}^{n} Xi}{n}$$

b/ standard deviation (s_D)

$s_D = k_n . R$

where k_n is coefficient 0.5908 for n = 3

$R = x_{max} - x_{min}$

c/ relative standard deviation (s_r) in %

$$s_r = \frac{s_D}{\overline{X}} .100$$

d/ standard measurement uncertainty

$$U_{Ai} = \sqrt{\frac{1}{n(n-1)}} \cdot \sum_{i=1}^{n} \left(X_i - \overline{X} \right)$$

$U = k \cdot u_A$, where k is the coefficient of the spread, k = 2, i.e. 95% probability that the true value lies within the uncertainty interval value.

Results and Discussion

The outputs of this study include information on:
- thermal processing of beef meat (boiling, stewing, roasting and frying)
- an overview of the results of thermal processing of different types of beef, i.e. the material balance of inputs and outputs of raw materials
- determination of basic components of raw and thermally processed meat

The results of thermal treatment of individual types of beef are given in Tables 2 to 4. Their yield overview is shown in Table 5. The basic chemical composition of the samples is summarised in Tables 6 to 8. While information about the chemical composition of various types of raw meat is generally available, data on the composition of thermally processed meat and the material balance of thermal processing is rare.

In the table below, the results of our study into the thermal processing of beef and its basic chemical compositions are supplemented by data regarding the weight of the samples collected.

Conclusions

The incoming weight of lean beef was 26.79 kg, and the samples used in the individual thermal processing experiments weighed 1 500 g each. The remaining raw meat was ground in a grinder (similarly as the thermally processed meats) and used for the determination of individual nutritional factors, of which only the basic ones are listed here.

Table 2. The material balance of thermal processing of lean beef meat (g)

	Sample						
	I	II	III	mean	SD	Sr (%)	SMI
			Boiling (2 h)				
inputs							
raw meat	1500.00	1500.00	1500.00	1500.00	0.00	0.00	0.00
drinking water	7500.00	7500.00	7500.00	7500.00	0.00	0.00	0.00
total	9000.00	9000.00	9000.00	9000.00	0.00	0.00	0.00
outputs							
boiled meat	735.00	735.00	715.00	728.30	11.80	1.60	0.26
broth	6605.00	6475.00	6670.10	6583.30	115.20	1.70	0.26
total	7340.00	7210.00	7385.00	7311.70	103.40	1.40	0.00
evaporation loss	1660.00	1790.00	1615.00	1688.30	103.40	6.10	0.26
			Stewing (2 h)				
inputs							
raw meat	1500.00	1500.00	1500.00	1500.00	0.00	0.00	0.00
drinking water	750.00	750.00	750.00	750.00	0.00	0.00	0.00
total	2250.00	2250.00	2250.00	2250.00	0.00	0.00	0.00
outputs							
stewed meat	815.00	800.00	770.00	795.00	26.60	3.30	0.00
juice	380.00	395.00	340.00	372.00	32.49	8.73	0.00
total	1195.00	1195.00	1110.00	1167.00	50.22	4.30	0.00
evaporation loss	1055.00	1055.00	1140.00	1083.00	50.22	4.64	8.21
			Roasting (2 h)				
inputs							
raw meat	1200.00	1200.00	1200.00	1200.00	0.00	0.00	0.00

Table 2. The material balance of thermal processing of lean beef meat (g)

	Sample						
	I	II	III	mean	SD	Sr (%)	SMI
			Roasting (2 h)				
inputs							
drinking water	120.00	120.00	120.00	120.00	0.00	0.00	0.00
total	1320.00	1320.00	1320.00	1320.00	0.00	0.00	0.00
outputs							
roasted meat	780.10	765.00	695.00	746.70	50.20	6.70	0.00
juice	190.00	140.00	195.00	175.00	32.50	18.60	0.00
total	970.10	905.00	890.00	921.70	47.30	5.10	0.00
evaporation loss	350.00	415.00	430.00	398.30	42.52	4.40	0.26
			Frying (15 min)				
inputs							
raw meat	1500.00	1500.00	1500.00	1500.00	0.00	0.00	0.00
pork fat	300.00	300.00	300.00	300.00	0.00	0.00	0.00
total	1800.00	1800.00	1800.00	1800.00	0.00	0.00	0.00
outputs							
fried meat	825.00	870.00	810.00	835.00	35.45	4.25	0.00
gravy	975.00	930.00	990.00	965.00	35.45	3.67	0.00

SMI - Standard measurement uncertainty

Table 3. The material balance of thermal processing of high-fat beef (g)

	Sample						
	I	II	III	mean	SD	Sr (%)	SMI
			Boiling (2 h)				
inputs							
raw meat	1500.00	1500.00	1500.00	1500.00	0.00	0.00	0.00
drinking water	7500.00	7500.00	7500.00	7500.00	0.00	0.00	0.00
total	9000.00	9000.00	9000.00	9000.00	0.00	0.00	0.00
outputs							
boiled meat	900.00	880.00	925.10	901.70	26.60	2.90	0.00
total broth removed	5700.00	5405.00	6195.10	5766.70	292.40	5.10	0.00
solidified fat*	125.00	125.10	115.00	121.70	5.90	4.90	0.00
total	6600.00	6285.00	7120.00	6668.30	493.30	7.40	0.26
evaporation loss	2400.10	2715.00	1880.00	2331.70	493.30	21.20	0.00
			Stewing (2 h)				
inputs							
raw meat	1500.00	1500.00	1500.00	1500.00	0.00	0.00	0.00
drinking water	750.00	750.00	750.00	750.00	0.00	0.00	0.00
total	2250.00	2250.00	2250.00	2250.00	0.00	0.00	0.00
outputs							
stewed meat	970.00	955.00	945.00	956.60	14.80	1.50	0.00
juice	380.00	370.00	330.00	360.00	29.50	8.20	0.00
total	1350.00	1325.00	1275.00	1316.60	44.30	41.50	0.00
evaporation loss	900.00	925.00	975.00	933.30	44.30	4.70	0.26

*solidified fat was removed and is therefore not included in the calculation

Table 4. The material balance of thermal processing of beef foreshank (g)

	Sample						
	I	II	III	mean	SD	Sr (%)	SMI
			Boiling (2 h)				
inputs							
raw meat	1500.00	1500.00	1500.00	1500.00	0.00	0.00	0.00
drinking water	7500.00	7500.00	7500.00	7500.00	0.00	0.00	0.00
total	9000.00	9000.00	9000.00	9000.00	0.00	0.00	0.00
outputs							
boiled meat	930.00	945.00	955.00	943.30	14.80	1.60	0.26
total broth removed	5000.00	5330.00	5520.00	5283.30	307.20	5.80	0.26
solidified fat*	19.30	34.70	25.10	26.30	9.10	34.50	0.00
total	5930.00	6275.00	6475.10	6226.70	322.00	5.20	0.00
evaporation loss	3070.00	2725.00	2525.00	2773.30	322.00	11.60	0.26
			Stewing (2 h)				
inputs							
raw meat	1500.00	1500.00	1500.00	1500.00	0.00	0.00	0.00
drinking water	750.00	750.00	750.00	750.00	0.00	0.00	0.00
total	2250.00	2250.00	2250.00	2250.00	0.00	0.00	0.00
outputs							
stewed meat	995.00	980.00	1000.00	991.70	11.80	1.20	0.00
juice	250.00	265.00	275.00	263.30	14.80	5.60	0.26
total	1245.00	1245.00	1275.00	1255.00	17.70	1.40	0.00
evaporation loss	1005.00	1005.00	975.00	995.00	17. 70	1.80	0.00

*solidified fat was removed and is therefore not included in the calculation
SMI - Standard measurement uncertainty

Table 5. Overview of thermally processed beef yields (g)

	Sample						
	I	II	III	mean	SD	Sr (%)	SMI
			leg				
boiled	49.00	49.00	47.70	48.50	0.77	1.60	0.00
stewed	54.30	53.30	51.30	52.90	1.77	3.30	0.00
roasted	52.00	51.00	46.30	49.70	3.37	6.80	0.37
fried	55.00	58.00	54.00	55.60	2.36	4.20	0.00
			high-fat				
boiled	60.00	58.70	61.70	60.10	1.77	2.90	0.26
stewed	64.70	63.70	63.00	63.80	1.00	1.60	0.00
			foreshank				
boiled	62.00	63.00	63.70	62.90	1.00	1.60	0.00
stewed	66.30	65.30	66.70	66.10	0.83	1.20	0.00

Table 6. Basic chemical composition of thermally processed lean beef (g/100 g)

	Sample						
	I	II	III	mean	SD	Sr (%)	SMI
			dry matter				
raw	23.80	26.60	24.4	24.90	1.65	6.60	0.26
boiled	40.00	43.50	41.50	41.60	2.07	5.00	0.00
broth	1.00	1.10	0.90	1.00	0.12	12.00	0.00
stewed	29.80	31.80	31.20	30.93	1.24	4.00	0.08
roasted	37.60	43.90	40.20	40.50	3.72	9.20	0.00
fried	43.10	45.20	44.20	44.10	1.24	2.80	0.00
			proteins				
raw	22.00	21.10	21.4	21.50	0.53	2.50	0.00
boiled	35.20	35.70	35.10	35.30	0.35	1.00	0.26
broth	0.60	0.60	0.60	0.60	0.00	0.00	0.00
stewed	26.30	25.30	27.60	26.40	1.36	5.10	0.00
roasted	32.20	34.10	33.30	33.20	1.12	3.40	0.00
fried	34.10	34.00	35.90	34.60	1.12	3.20	0.00
			total lipids				
raw	1.35	4.53	1.66	2.51	1.88	74.90	0.08
boiled	1.82	5.42	2.38	3.20	2.13	66.30	0.00
broth	-	-	-	-	-	-	-
stewed	1.58	4.12	1.48	2.39	1.50	62.80	0.08
roasted	1.80	5.79	2.36	3.31	2.36	71.10	0.00
fried	3.67	7.17	3.59	4.81	2.11	43.90	0.00
			ash				
raw	1.09	1.05	1.08	1.07	0.02	1.90	0.08
boiled	0.57	0.58	0.57	0.57	0.01	1.70	0.08
broth	0.21	0.22	0.21	0.21	0.01	4.80	0.08
stewed	1.35	1.32	1.48	1.38	0.09	6.80	0.08
roasted	1.72	1.81	1.84	1.79	0.07	3.90	0.00
fried	1.20	1.18	1.19	1.19	0.01	0.80	0.00

Table 7. Basic chemical composition of thermally processed high-fat beef (g/100 g)

	Sample						
	I	II	III	mean	SD	Sr (%)	SMI
			dry matter				
raw	48.00	45.30	41.4	44.9	3.90	8.70	0.00
boiled	61.40	58.10	61.10	60.20	1.95	7.70	0.00
broth	0.70	0.80	0.60	0.70	0.12	17.10	0.00
stewed	51.20	54.70	54.60	51.80	2.89	5.60	1.84
			proteins				
raw	12.50	15.10	15.9	14.5	2.01	13.50	0.00
boiled	22.10	23.70	20.20	20.00	2.07	9.40	2.00
broth	0.40	0.50	0.40	0.40	0.06	15.00	0.26
stewed	16.40	19.00	17.70	17.70	1.54	8.70	0.00
			total lipids				
raw	33.00	29.40	27.1	29.8	3.48	11.70	0.26

Table 7. Basic chemical composition of thermally processed high-fat beef (g/100 g)

	Sample						
	I	II	III	mean	SD	Sr (%)	SMI
			total lipids				
boiled	39.20	34.20	40.00	37.80	3.43	9.10	0.00
broth	2.20	2.30	1.90	2.10	0.24	11.40	0.26
stewed	33.20	29.50	37.20	33.30	4.55	13.70	0.00
			ash				
raw	0.69	0.72	0.73	0.71	0.02	2.80	0.08
boiled	0.40	0.41	0.36	0.39	0.03	7.70	0.00
broth	0.17	0.19	0.16	0.17	0.02	11.40	0.08
stewed	0.81	0.90	0.85	0.85	0.05	5.90	0.08

The total lipid content was calculated by converting the removed solidified fat to 100 g of broth

Table 8. Basic chemical composition of thermally processed beef foreshank (g/100 g)

	Sample						
	I	II	III	mean	SD	Sr (%)	SMI
			dry matter				
raw	28.00	28.70	28.30	28.33	0.41	1.40	0.08
boiled	37.20	37.70	36.20	37.00	0.89	2.40	0.26
broth	1.20	1.20	1.20	1.20	0.00	0.00	0.00
stewed	32.50	34.70	32.10	33.10	1.54	4.60	0.00
			proteins				
raw	19.70	19.60	20.6	19.90	0.59	3.00	0.36
boiled	28.40	29.60	30.20	29.40	1.06	3.60	0.00
broth	0.90	0.80	0.80	0.80	0.06	7.30	0.26
stewed	24.60	24.80	25.10	24.80	0.29	1.20	0.26
			total lipids				
raw	5.97	7.24	6.02	6.41	0.75	11.70	0.00
boiled	6.97	7.00	6.66	6.87	0.20	2.90	0.12
broth	0.22	0.65	0.45	0.44	0.25	56.80	0.00
stewed	5.96	8.76	5.91	6.87	1.68	24.50	0.12
			ash				
raw	0.97	0.95	0.99	0.97	0.01	1.00	0.00
boiled	0.48	0.44	0.41	0.44	0.04	9.70	0.08
broth	0.25	0.25	0.23	0.24	0.01	4.10	0.08
stewed	1.22	1.21	1.18	1.20	0.02	1.70	0.08

The total lipid content was calculated by converting the removed solidified fat to 100 g of broth

The incoming weight of high-fat beef was 16.5 kg, and the samples used for thermal processing weighed 1 500 g each. The incoming weight of beef foreshank was 15.06 kg, and the samples used for thermal processing also weighed 1 500 g each.

Detailed results of the thermal treatment of the samples are summarised in Tables 2 to 4, from which we selected and calculated yields of thermally processed meat (Table 5). With respect to this table, we should add that boiled and fried samples were merely ground prior to analysis.

Table 9. Inputs and trimmings of lean and high-fat beef and beef foreshank

Sample	input (g)	trimmings (g)	(%)	experiment inputs (g)
lean				
I	8 350	497	5.62	8 847
II	9 135	675	7.98	8 460
III	10 170	680	7.17	9 490
total	27 655	1 845	20.77	26 790
high-fat				
total	-	-	-	16 500
foreshank				
total	-	-	-	15 060

The stewed and roasted samples were weighed and their yield calculated. They were then ground and properly mixed after the corresponding juice had been added.

Data on the main components in the thermally processed samples, i.e. the content of dry matter, proteins, total lipids and ash, as determined in our study, is summarised in Tables 6 to 8. In each sample subgroup, only mean values of individual components are given, which are averaged values from two or three measurements. These results were processed and their s_D and s_r (%) values computed.

The lowest dry matter content in raw beef was found in lean meat samples (on average 24.9%), the highest in high-fat meat (on average 44.9%). The mean dry matter content in beef foreshank samples was 28.3%. Similar values were also found in thermally processed samples. Detained data on the content of other components is given in the appropriate tables designed for easy navigation.

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