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ABSTRACT

Ultimate pH value and instrumental colour (CIE*L*a*b** values) characteristics, proximate (moisture, protein, total fat and total ash) and mineral composition (K, P, Na, Mg, Ca, Zn, Fe, Cu, Ni and Mn) were determined in 10 (heart, tongue, lungs, spleen, liver, kidney, brain, testicle, thymus and kidney fat) edible by-products of Saanen goat male kids. Many significant or numerical differences were found in the mean values of quality characteristics among the edible by-products. Among edible organs and glands, liver had the lowest surface CIE*L** value (darkest colour), and the highest levels of protein, Zn, Cu and Mn. Furthermore, the highest pH_{24h}, total ash, K, P and Mg levels were determined in the thymus. The testicle had the highest moisture, Ca and Ni levels. The spleen had the lowest fresh cut cross-section CIE*L** value (darkest colour), and the highest Fe level. The highest total fat content and Na level were determined in the brain and kidney, respectively. Among all the edible by-products, kidney fat had the highest pH_{24h}, surface CIE*L** value (lightest colour) and total fat content, and the lowest moisture, protein, total ash, K, P, Na, Mg, Ca, Zn, Fe, Cu, Ni and Mn levels.

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1. Introduction

Goats, the earliest ruminant to be domesticated, are traditional sources of meat, milk, fibre, leather, related products of animal origin and are used as draught and pack animals (Casey & Webb 2010; Argüello 2011).

In general, the number of goats, as well as goat meat production, has increased worldwide over past years (Argüello 2011; FAOSTAT 2015). In Serbia, no statistical records were kept concerning the number of goats and their breeding because goat keeping was banned by law after the Second World War for a long period (Memiši et al. 2009; Žujović et al. 2009). This law was, fortunately, never fully implemented, but resulted in a lack of knowledge of the goat population size in the past. In 2014, The Statistical Office of the Republic of Serbia reported the Serbian goat population to be 219,000 head.

The most important category of goat meat in Serbia, as in developed countries, is kid meat (Žujović et al. 2009). The greatest demand for young goats in Serbia occurs seasonally during spring. Production is based on various breeds, more or less locally determined. In some regions, production systems of goats are quite extensive. The number of kids (and goats) that are slaughtered annually in Serbia is considerable. Meat from these animals, however, is not available on the market, since most kids and even adult goats are slaughtered and consumed on the farms where they were raised (Memiši et al. 2009; Žujović et al. 2009).

Traditionally, kids are slaughtered at 3–7 months old and 12–15 kg carcass weight (Peña et al. 2009). According to Serbian legislation (1974), kids are normally slaughtered between 3 weeks and 6 months of age. The carcass weight with head, liver, heart, lungs, kidney and internal fat and without skin and distal parts of the legs should be between 4 and 12 kg.

Over the past decade, farmers in Vojvodina have become interested in goat breeding, especially raising noble, highly yielding breeds. As there were few such goats in the country, they have been imported on several occasions; these imports were Alpine, Saanen and German fawn dairy goats (Krajinović et al. 2011). In farms keeping dairy goats, male kids are considered as a by-product. Therefore, to save the milk for the dairy industry, goat keepers remove the kids from their dams very early in the postnatal period, and the kids are then raised under an intensive system. Goat kids in intensive dairy goat farms are usually reared on milk replacers (Marichal et al. 2003; Argüello et al. 2005, 2012; Zurita-Herrera et al. 2013). It is well known that young animals fed high concentrate diets generally have higher daily gains, dressing percentage and carcass quality than those produced in a forage system.

Saanen dairy goats, which originated in the Saanen valley of Switzerland, are very famous for their prolific milk production, as well as for being the largest of the dairy goat breeds (Encyclopedia Britannica 2015).

Meat is the major product of the goat, as all goats can produce meat (Mahgoub et al. 2012). Goldstrand (1988)

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Table 1. Feeding schedule for goat kids.

Age	Feed	Quantity	Frequency
Birth-3 days	Colostrum	600–800 ml/day	4 times/day
4–10 days	Colostrum and goat milk	1–1.5 l/day	4 times/day
11–17 days	Milk replacer	Free choice	N/A
18–31 days	Milk replacer	Free choice	N/A
	Alfalfa hay	Free choice	N/A
	Water	Free choice	N/A
31 days-slaughter	Milk replacer	Free choice	N/A
	Alfalfa hay	Free choice	N/A
	16% starter grain	About 150 g/day	3 times/day
	Water	Free choice	N/A

Note: N/A = not applicable.

calculates that organs, fatty tissues, bones and blood represent 39.30% and 35% of the live weight of cattle, pigs and lambs or goats, respectively.

The available scientific literature mainly describes sensory, technological and nutritional quality of goat meat, but little or no information is available for some edible by-products. Edible by-products can be categorized into edible organs, glands, and edible fats (Spooncer 1988; Ockerman & Basu 2004). Edible offal, or variety meat, is also a form of meat which is used as food, but which is not skeletal muscles, and, in general, it possesses higher levels of some micronutrients, especially minerals and vitamins, than muscular tissue (Anderson 1988; Goldstrand 1988; Ockerman & Basu 2004; Lawrie & Ledward 2006; Honikel 2011). Also, edible organs and glands are often different from skeletal tissue in structure, composition, functional and sensory properties (Spooncer 1988; Ockerman & Basu 2004). According to Serbian legislation (1974), the edible organs and glands (edible offal) of a butchered goat that are removed in dressing include brain, tongue, heart, lungs, thymus, liver, spleen, kidneys and testicles.

Animal fat is important for human nutrition for its high energy value, which is more than twice that of carbohydrates (Wood 1984). The ascending order of fat deposition in goats was: subcutaneous, intermuscular, mesenteric, kidney knob and channel and omental fat (Mahgoub et al. 2012).

Edible by-products from goat slaughter are part of the diet in different countries worldwide (Nollet & Toldrá 2011), as a component of kitchen-style food preparations or as processed meat products (Ockerman & Basu 2004; Dalmás et al. 2011; Toldrá et al. 2012; de Queiroz et al. 2013). Therefore, the aim of this study was to determine the ultimate pH and colour characteristics and proximate and mineral composition of 10 edible by-products (heart, tongue, lungs, spleen, liver, kidney, brain, testicle, thymus and kidney fat) from intensively reared Saanen goat male kids. This is important to provide, update and improve regular nutrient composition data of goat edible by-products.

2. Materials and methods

This study included 20 Saanen male kids. All kids were raised under identical husbandry, management and feeding conditions. At birth, all kids were removed from their dams and housed individually until they were 10 days old. From the tenth day until slaughter, the kids were housed in pens, with 30 animals per pen. The feeding schedule for the kids is presented in Table 1 (Belanger 2001), and the chemical composition of the diet is presented in Table 2. Age and body weight at slaughter ranged from 67 to 83 days and from 19.5 to 23.9 kg.

At the end of the fattening period, all kids were transported to a commercial abattoir. Kids were held overnight without feed before slaughter. Kids were slaughtered and dressed using standard commercial procedures. After evisceration, kidney fat and the following nine edible organs and glands items were collected from each kid: heart, tongue, lungs, spleen, liver, kidney, brain, testicle and thymus (Spooncer 1988). All items were packed individually in clean polyethylene bags within 1 h of the animal's slaughter, and conventionally chilled overnight in a chiller at 0–4°C.

Table 2. Chemical composition of the diet.

Commercial milk replacer	Quantity	Alfalfa hay (Belanger, 2001)	%	Commercial 16% starter grain	Quantity
Crude fat	24.0%	Crude protein	15.3	Protein	Min. 16%
Crude protein	24.0%	Digestible protein	10.9	Fibre	Max. 8%
Lysine	1.8%	Fat	1.9	Ash	Max. 8%
Methionine	0.3%	Fibre	28.6	Moisture	Max. 13.5%
Calcium	1.0%	Nitrogen-free	36.7	Calcium	0.80–1.00%
Phosphor	0.7%	Mineral matter	8.0	Phosphor	Min. 0.5– 0.7%
Magnesium	0.2%	Calcium	1.47	Sodium	0.20–0.30%
Moisture	to 8.0%	Phosphorus extract	0.24	Oats units/kg (calculated value)	0.90%
Crude fibre	1.0%			Vitamin A	7,500 IJ
Crude ash	8.3%			Vitamin D_3	1,200 IJ
Vitamin A	50.000 IU			Vitamin E	15 mg
Vitamin D_3	5.000 IU			Vitamin B_1	1.5 mg
Vitamin E	100 mg			Vitamin B_2	2.0 mg
Biotin	0.200 mg			Vitamin B_{12}	0.010 mg
Iron	140 mg			Pantothenic acid	10 mg
Vitamin B_1	10 mg			Nicotinic acid	10 mg
Vitamin B_2	10 mg			Iron	50 mg
Vitamin B_6	5 mg			Copper	5 mg
Vitamin B_{12}	0.025 mg			Manganese	30 mg
Ca-D- pantothenate	20 mg			Zinc	50 mg
Nicotinic acid	30 mg			Iodine	0.6 mg
Folic acid	1 mg			Cobalt	0.10 mg
Vitamin C	100 mg			Selenium	0.10 mg
Choline chloride	900 mg			Magnesium	50 mg
Selenium	0.3 mg			Antioxidant	100 mg
Enterococcus faecium M74 – NICMB 11181	0.8×10^9 CFU				

Ultimate pH and colour characteristics were measured on the surface and/or centre cross-section of the fresh offal and kidney fat. After determination of ultimate pH and colour characteristics, the remaining part of each offal item and kidney fat was individually homogenized (Waring 8010ES Blender, USA; capacity 1 l, speed 18,000 rpm, duration of homogenization 10 s, temperature after homogenization <10°C), vacuum packaged in polyethylene bags and stored at −40°C until determination of proximate and mineral composition.

The pH value was measured at 24 h (pH_{24h}) *post-mortem* using a portable pH meter (Consort T651, Turnhout, Belgium) equipped with an insertion glass combination electrode (Mettler Toledo Greifensee, Switzerland). The pH meter was calibrated before and during the readings using standard phosphate buffers (pH value of calibration buffers was 7.00 and 4.01 at 25°C) and adjusted to the expected temperature of measured muscles (ISO 2917 1999).

Six replicate surface and/or centre cross-section colour measurements were performed after 60 min of blooming at 3°C (Honikel 1998). The CIE*L** (lightness), CIE*a** (redness) and CIE*b** (yellowness) colour coordinates (CIE 1976) were determined using a Konica Minolta Chroma Meter CR-400 (Minolta Co., Ltd., Osaka, Japan) using D_{65} illuminant, a 2° standard observer angle and an 8-mm aperture in the measuring head. The instrument was standardized with a white plate ($Y = 92.9$, $x = 0.3159$ and $y = 0.3322$), and warmed according to the manufacturer's instructions.

Moisture (ISO 1442 1997), protein (nitrogen × 6.25; ISO 937 1978), total fat (ISO 1443 1973) and total ash (ISO 9361998) levels in the edible organs, glands and fat were determined according to methods recommended by the International Organization for Standardization.

The levels of all elements, [potassium (K), sodium (Na), magnesium (Mg), calcium (Ca), zinc (Zn), iron (Fe), copper (Cu), nickel (Ni) and manganese (Mn)], except phosphorus (P), were determined in the organs, glands and fat using inductively coupled plasma-optical emission spectrometry (ICP-OES) (iCP 6000 Series, Thermo Scientific, Cambridge, UK), after dry ashing mineralization as described in detail in Tomović et al. (2011). The total phosphorous (P) content was determined according to the ISO method (ISO 13730 1996).

3. Results and discussion

3.1. Ultimate pH and colour characteristics

Results for ultimate pH value and instrumental colour (CIE*L*a*b** values) of all edible by-products of Saanen goat male kids are presented in Table 3. In this study, ultimate pH and colour were significantly affected by the type of by-product ($P < .05$).

Kidney fat had the highest mean ultimate pH (6.67; $P < .05$) among all investigated edible by-products. Among all edible organs and glands, the mean pH_{24h} was highest ($P < .05$) for brain and thymus (6.43, 6.49, respectively; $P > .05$). Lungs, spleen, liver and testicle (6.30, 6.34, 6.33, 6.30, respectively; $P > .05$) had higher ($P < .05$) mean pH_{24h} than kidney (6.12). The lowest mean pH_{24h} ($P < .05$) was determined in the heart and tongue (5.65, 5.65, respectively, $P > .05$), and these were in the range characteristic for red (goat) meat (Honikel 1999; Madruga et al. 2008; Sebsibe 2008).

According to Florek et al. (2012), the distinction made between offal as derived mainly from organ tissue and those originating from muscular tissue is crucial because of differences in their potential to sustain quality.

The *post-mortem* pH of meat is determined by the amount of lactic acid produced from glycogen during anaerobic glycolysis (Lawrie & Ledward 2006). With the exception of liver, offal contains low levels of carbohydrates, being quite similar to, or lower than, levels in lean meat. The liver normally has about 5.3% carbohydrate, mainly as glycogen (Savell & Pearson 1988). The pH is a very important criterion for meat and meat products' quality. An ultimate pH above 5.85 shortens the shelf life (Gill 1988; Honikel 1999; Lawrie & Ledward 2006).

Kidney fat had the highest surface CIE*L** value (75.60). There were significant ($P < .05$) differences in surface CIE*L** value among the particular edible organ and gland items, except between heart and spleen, heart and kidney, tongue and testicle, and brain and thymus ($P > .05$). Among the edible organs and glands, liver had the lowest mean surface CIE*L** value (35.76; $P < .05$), that is, darkest colour, while brain and thymus had the highest mean surface CIE*L** value ($P < .05$), that is, lightest colour (64.45, 64.65, respectively; $P > .05$). Lungs had the highest mean surface CIE*a** value (27.47; $P < .05$). The lowest mean surface CIE*a** value (6.28; $P < .05$) was determined in kidney fat, followed by tongue (8.23), with a significant ($P < .05$) difference between them. The mean surface CIE*b** value was numerically the highest for the kidney (12.57), while the lowest mean surface CIE*b** value (0.94; $P < .05$) was determined in the spleen. Except between the heart and kidney, mean fresh cut cross-section CIE*L** values differed significantly ($P < .05$) among all investigated edible organs and glands, being the lowest (darkest colour) in the spleen (26.48; $P < .05$), and the highest (lightest colour) in the thymus (66.57; $P < .05$) (fresh cut cross-section colour, CIE*L*a*b** values, for the brain and kidney fat were not determined). The mean fresh cut cross-section CIE*a** value differed significantly ($P < .05$) among all investigated edible organs and glands, except for the liver and kidney. Lungs had the highest (26.26; $P < .05$) and the thymus had the lowest (8.85; $P < .05$) mean fresh cut cross-section CIE*a** value. The mean fresh cut cross-section CIE*b** value was highest ($P < .05$) in the lungs and liver (11.47, 10.60, respectively, $P > .05$) and the lowest in the testicle (−0.59; $P < .05$). The difference between surface and fresh cut cross-section colour parameters (CIE*L*a*b** values) was not significant ($P > .05$) for the heart (CIE*b** value), lungs (CIE*a**and CIE*b** values), liver (CIE*L** and CIE*a** values), testicle (CIE*a** values) and thymus (CIE*L** and CIE*a** values).

3.2. Proximate composition

Moisture, protein, total fat and total ash contents of all edible by-products of Saanen goat male kids are presented in Table 4. The proximate composition was significantly influenced by the type of by-products.

Among all investigated edible by-products, kidney fat had the highest mean total fat content (89.66 g/100 g; $P < .05$) and

Table 3. Ultimate pH and colour characteristics of edible organs, glands and kidney fat from Saanen goat male kids.

		pH value	SC			FCCSC			Significant differences between SC and FCCSC		
Edible by-products		pH_{24h}	CIE*L** (lightness)	CIE*a** (redness)	CIE*b** (yellowness)	CIE*L** (lightness)	CIE*a** (redness)	CIE*b**(yellowness)	CIE*L**	CIE*a**	CIE*b**
Heart	X ± SD	5.65 ± 0.07^{e}	42.57 ± 2.03^{ef}	17.09 ± 0.87^{b}	7.54 ± 1.15^{d}	39.40 ± 0.79^{e}	21.70 ± 0.52^{c}	6.84 ± 0.46^{c}	*	*	ns
	Range	5.53–5.74	39.45–45.52	15.98–18.34	5.85–9.34	38.07–40.66	20.94–22.53	6.28–7.52			
Tongue	X ± SD	5.65 ± 0.06^{e}	60.34 ± 1.05^{c}	8.23 ± 0.87^{e}	5.19 ± 0.56^{e}	44.12 ± 1.59^{d}	19.96 ± 0.66^{d}	6.54 ± 0.67^{cd}	*	*	*
	Range	5.57–5.75	58.82–61.91	7.08–10.12	4.53–6.30	42.51–46.86	19.05–20.96	5.61–7.84			
Lungs	X ± SD	6.30 ± 0.12^{c}	52.57 ± 3.79^{d}	27.47 ± 2.22^{a}	11.81 ± 2.04^{ab}	56.30 ± 1.75^{c}	26.26 ± 1.38^{a}	11.47 ± 0.72^{a}	*	ns	ns
	Range	6.12–6.50	48.09–58.80	25.20–30.37	8.67–16.17	52.76–58.71	23.88–28.83	10.22–12.40			
Spleen	X ± SD	6.34 ± 0.09^{c}	41.49 ± 2.01^{f}	13.64 ± 1.06^{c}	0.94 ± 1.24^{f}	26.48 ± 1.91^{g}	23.37 ± 1.75^{b}	5.23 ± 0.50^{e}	*	*	*
	Range	6.13–6.44	39.10–44.85	11.95–15.75	−0.91–2.66	22.95–28.72	20.34–26.37	4.49–6.04			
Liver	X ± SD	6.33 ± 0.07^{c}	35.76 ± 1.52^{g}	17.47 ± 0.83^{b}	11.73 ± 1.14^{ab}	35.52 ± 1.16^{f}	17.77 ± 1.21^{e}	10.60 ± 0.91^{a}	ns	ns	*
	Range	6.24–6.49	33.25–38.42	16.33–18.42	10.05–13.48	33.49–37.32	15.92–19.13	8.74–11.94			
Kidney	X ± SD	6.12 ± 0.14^{d}	44.33 ± 2.23^{e}	14.20 ± 1.28^{c}	12.57 ± 0.90^{a}	40.36 ± 2.37^{e}	16.77 ± 1.37^{e}	5.69 ± 1.18^{de}	*	*	*
	Range	5.93–6.33	40.09–46.77	11.76–15.77	10.99–13.59	35.46–43.91	14.54–18.75	3.05–7.22			
Brain	X ± SD	6.43 ± 0.08^{b}	64.45 ± 1.47^{b}	13.67 ± 0.96^{c}	11.09 ± 0.71^{bc}	NM	NM	NM			
	Range	6.23–6.53	61.62–67.05	12.18–15.56	9.88–12.14						
Testicle	X ± SD	6.30 ± 0.11^{c}	60.69 ± 3.64^{c}	11.69 ± 3.63^{d}	7.62 ± 0.90^{d}	64.47 ± 2.41^{b}	11.43 ± 1.02^{f}	-0.59 ± 1.69^{f}	*	ns	*
	Range	6.04–6.39	53.61–65.15	7.42–20.72	6.11–9.10	60.55–68.37	10.15–13.00	−2.97–1.83			
Thymus	X ± SD	6.49 ± 0.06^{b}	64.65 ± 2.61^{b}	10.47 ± 2.18^{d}	10.10 ± 1.21^{c}	66.57 ± 1.70^{a}	8.85 ± 2.65^{g}	8.86 ± 1.12^{b}	ns	ns	*
	Range	6.42–6.62	61.77–69.68	6.81–14.50	8.60–12.08	64.83–69.82	5.20–13.81	7.46–11.05			
Kidney fat	X ± SD	6.67 ± 0.09^{a}	75.60 ± 1.63^{a}	6.28 ± 1.25^{f}	7.29 ± 1.21^{d}	NM	NM	NM			
	Range	6.54–6.80	72.63–77.55	4.71–8.94	5.61–9.35						
P value		<.001	<.001	<.001	<.001	<.001	<.001	<.001			

Notes: SC: Surface colour; FCCSC: Fresh cut cross-section colour; NM: not measured; ns: indicates no significant difference ($P > .05$).
^{a,b,c,d,e,f,g} within each column, numbers with different superscript letters are significantly different ($P < .05$).
*: indicates a significant difference at $P < .05$.

Table 4. Proximate composition (g/100 g) of edible organs, glands and kidney fat from Saanen goat male kids.

Edible by-products		Moisture	Protein	Total fat	Total ash
Heart	X ± SD	79.41 ± 0.46^{d}	15.84 ± 0.32^{d}	3.36 ± 0.55^{d}	1.09 ± 0.03^{d}
	Range	78.87–80.12	15.29–16.29	2.62–4.45	1.04–1.14
Tongue	X ± SD	74.99 ± 0.85^{f}	17.20 ± 0.43^{b}	6.54 ± 0.87^{c}	0.95 ± 0.06^{e}
	Range	73.72–76.08	16.58–17.97	5.58–8.21	0.86–1.04
Lungs	X ± SD	80.27 ± 0.69^{c}	15.89 ± 0.56^{d}	2.32 ± 0.33^{ef}	1.26 ± 0.04^{c}
	Range	79.08–81.25	15.21–17.11	1.85–2.78	1.20–1.32
Spleen	X ± SD	78.38 ± 0.77^{e}	18.26 ± 0.44^{a}	1.85 ± 0.28^{fg}	1.46 ± 0.06^{b}
	Range	77.68–80.01	17.53–18.89	1.50–2.31	1.37–1.58
Liver	X ± SD	74.40 ± 0.64^{f}	18.43 ± 0.64^{a}	3.41 ± 0.34^{d}	1.48 ± 0.05^{b}
	Range	73.47–75.17	17.59–19.78	2.85–3.88	1.39–1.57
Kidney	X ± SD	80.96 ± 0.54^{b}	15.18 ± 0.46^{e}	2.30 ± 0.17^{ef}	1.26 ± 0.04^{c}
	Range	80.06–81.87	14.50–16.01	1.95–2.62	1.20–1.32
Brain	X ± SD	81.57 ± 0.51^{b}	9.69 ± 0.24^{g}	7.13 ± 0.46^{b}	1.47 ± 0.06^{b}
	Range	80.64–82.27	9.28–10.16	6.44–8.07	1.39–1.55
Testicle	X ± SD	85.01 ± 0.49^{a}	12.23 ± 0.50^{f}	1.57 ± 0.14^{g}	0.99 ± 0.05^{e}
	Range	84.23–85.54	11.42–13.03	1.33–1.75	0.89–1.05
Thymus	X ± SD	79.12 ± 0.71^{d}	16.31 ± 0.29^{c}	2.48 ± 0.54^{e}	2.02 ± 0.09^{a}
	Range	78.09–80.29	15.80–16.69	1.89–3.48	1.88–2.14
Kidney fat	X ± SD	8.88 ± 1.17^{g}	1.28 ± 0.31^{h}	89.66 ± 1.38^{a}	0.04 ± 0.01^{f}
	Range	6.71–10.47	0.95–1.74	87.69–92.24	0.03–0.05
P value		<.001	<.001	<.001	<.001

^{a,b,c,d,e,f,g,h} within each column, numbers with different superscript letters are significantly different ($P < .05$).

Table 5. Mineral composition (mg/100 g) of edible organs, glands and kidney fat from Saanen goat male kids.

Edible by-products		*K*	*P*	Na	Mg	Ca
Heart	X ± SD	277 ± 8de	226 ± 8^{g}	72.5 ± 4.0^{e}	20.1 ± 0.8^{b}	10.7 ± 1.9^{c}
	Range	269–291	210–238	67.6–80.5	18.7–21.4	7.1–13.7
Tongue	X ± SD	266 ± 15^{e}	220 ± 16^{g}	77.1 ± 4.7^{e}	19.9 ± 0.8^{bc}	17.4 ± 2.2^{a}
	Range	248–288	191–251	69.1–84.1	19.0–21.6	14.9–20.6
Lungs	X ± SD	280 ± 17de	266 ± 20^{e}	121 ± 7^{c}	14.5 ± 0.7^{f}	15.1 ± 1.7^{ab}
	Range	243–304	231–298	110–134	13.7–15.7	12.6–18.9
Spleen	X ± SD	371 ± 24^{b}	345 ± 18^{b}	64.6 ± 7.0^{f}	19.2 ± 1.1^{cd}	17.1 ± 3.0^{a}
	Range	327–412	315–374	55.4–73.3	17.8–20.9	13.2–21.5
Liver	X ± SD	291 ± 17^{cd}	359 ± 18^{b}	63.5 ± 4.4^{f}	19.0 ± 1.0^{d}	14.2 ± 4.1^{b}
	Range	263–317	329–390	58.8–71.6	17.6–20.1	9.9–20.2
Kidney	X ± SD	235 ± 19^{f}	283 ± 10^{d}	167 ± 9^{a}	17.6 ± 1.1^{e}	16.6 ± 3.0^{ab}
	Range	204–263	266–296	155–183	15.4–19.1	12.0–21.7
Brain	X ± SD	302 ± 22^{c}	317 ± 21^{c}	137 ± 7^{b}	11.2 ± 0.4^{h}	15.4 ± 2.0^{ab}
	Range	265–338	280–352	126–147	10.6–12.1	13.4–20.0
Testicle	X ± SD	297 ± 21^{cd}	245 ± 11^{f}	113 ± 12^{d}	13.3 ± 0.8^{g}	17.6 ± 2.8^{a}
	Range	252–322	227–259	99–137	12.1–15.0	13.5–22.1
Thymus	X ± SD	444 ± 39^{a}	516 ± 28^{a}	59.6 ± 4.1^{f}	21.7 ± 1.2^{a}	14.9 ± 3.1^{ab}
	Range	385–530	465–555	51.9–64.9	20.2–24.9	11.9–23.2
Kidney fat	X ± SD	17.0 ± 2.5^{g}	11.1 ± 2.3^{h}	22.4 ± 4.4^{g}	1.22 ± 0.21^{i}	10.0 ± 3.3^{c}
	Range	14.0–22.0	8.0–14.1	17.6–30.7	0.94–1.58	5.5–15.5
P value		<.001	<.001	<.001	<.001	<.001

Edible by-products		Zn	Fe	Cu	Ni	Mn
Heart	X ± SD	1.49 ± 0.16^{de}	3.02 ± 0.20^{d}	0.40 ± 0.04^{c}	0.032 ± 0.008^{bc}	0.015 ± 0.001^{f}
	Range	1.25–1.76	2.60–3.32	0.34–0.47	0.021–0.046	0.012–0.017
Tongue	X ± SD	2.29 ± 0.12^{bc}	2.02 ± 0.18^{e}	0.18 ± 0.02^{def}	0.019 ± 0.006^{cde}	0.024 ± 0.002^{def}
	Range	1.96–2.53	1.83–2.39	0.14–0.21	0.010–0.029	0.021–0.028
Lungs	X ± SD	1.98 ± 0.65^{bc}	4.94 ± 1.30^{c}	0.20 ± 0.04^{de}	0.018 ± 0.006^{de}	0.021 ± 0.006^{ef}
	Range	1.47–3.23	3.20–7.16	0.15–0.25	0.011–0.026	0.015–0.031
Spleen	X ± SD	2.08 ± 0.17^{bc}	12.8 ± 2.0^{a}	0.084 ± 0.007^{fg}	0.014 ± 0.006^{e}	0.031 ± 0.005^{cd}
	Range	1.89–2.47	9.3–15.5	0.066–0.092	0.007–0.024	0.023–0.038
Liver	X ± SD	4.78 ± 1.00^{a}	7.78 ± 1.46^{b}	2.62 ± 0.35^{a}	0.028 ± 0.030^{bcd}	0.21 ± 0.03^{a}
	Range	3.53–5.98	5.55–9.45	2.11–3.14	0.010–0.113	0.18–0.26
Kidney	X ± SD	2.44 ± 0.67^{b}	3.11 ± 0.34^{d}	0.55 ± 0.04^{b}	0.019 ± 0.009^{cde}	0.067 ± 0.004^{b}
	Range	1.56–3.77	2.69–3.83	0.47–0.59	0.008–0.039	0.060–0.074
Brain	X ± SD	1.10 ± 0.13^{e}	1.14 ± 0.20^{f}	0.27 ± 0.04^{d}	0.034 ± 0.024^{ab}	0.028 ± 0.004^{cde}
	Range	0.93–1.39	0.86–1.38	0.22–0.35	0.016–0.080	0.022–0.035
Testicle	X ± SD	1.87 ± 0.43^{cd}	2.63 ± 0.38^{de}	0.098 ± 0.029^{efg}	0.046 ± 0.016^{a}	0.036 ± 0.006^{c}
	Range	1.43–2.72	2.03–3.38	0.031–0.137	0.028–0.075	0.022–0.042
Thymus	X ± SD	2.01 ± 0.21^{bc}	0.89 ± 0.32^{f}	0.057 ± 0.009^{g}	0.012 ± 0.004^{e}	0.021 ± 0.005^{ef}
	Range	1.70–2.34	0.57–1.42	0.040–0.070	0.005–0.019	0.014–0.033
Kidney fat	X ± SD	0.16 ± 0.03^{f}	0.19 ± 0.04^{g}	0.021 ± 0.003^{h}	0.008 ± 0.002^{e}	0.004 ± 0.001^{g}
	Range	0.11–0.22	0.14–0.25	0.017–0.028	0.005–0.012	0.003–0.005
P value		<.001	<.001	<.001	<.001	<.001

^{a,b,c,d,e,f,g,h,i} within each column, numbers with different superscript letters are significantly different ($P < .05$).

the lowest mean moisture (8.88 g/100 g; $P < .05$), protein (1.28 g/100 g; $P < .05$) and total ash (0.04 g/100 g; $P < .05$) levels.

The testicle had the highest mean moisture level of all edible organ and gland items (85.01 g/100 g; $P < .05$), while the tongue and liver (74.99 and 74.40 g/100 g, respectively; $P > .05$) had the lowest mean moisture level ($P < .05$). Furthermore, the spleen and liver had the highest mean protein content (18.26 and 18.43 g/100 g, respectively; $P > .05$), and the brain had the lowest mean protein content (9.69 g/100 g; $P < .05$). The mean total fat content was highest in the brain (7.13 g/100 g; $P < .05$), while numerically the lowest mean total fat content was in the testicle (1.57 g/100 g). The thymus had the highest mean total ash level (2.02 g/100 g; $P < .05$), while the lowest mean total ash levels ($P < .05$) were found in the tongue and testicle (0.95 and 0.99 g/100 g, respectively, $P > .05$). There is a lack of information about proximate composition of by-products from goat kids. Levels of moisture and total fat for goat heart, liver and kidney obtained in this study are in agreement with the results of Park et al. (1991).

3.3. Mineral composition

Mineral (K, P, Na, Mg, Ca, Zn, Fe, Cu, Ni and Mn) levels of all edible by-products of Saanen goat male kids are presented in Table 5(a) and (b). The mineral composition was significantly influenced by the type of by-product.

Among all investigated edible by-products, kidney fat ($P < .05$) had the lowest mean K (17.0 mg/100 g), P (11.1 mg/100 g), Na (22.4 mg/100 g), Mg (1.22 mg/100 g), Zn (0.16 mg/100 g), Fe (0.19 mg/100 g), Cu (0.021 mg/100 g) and Mn (0.004 mg/100 g) levels and numerically the lowest mean Ca (10.0 mg/100 g) and Ni levels (0.008 mg/100 g).

Among all investigated edible organs and glands, the highest mean K level ($P < .05$) was in the thymus (444 mg/100 g), while the lowest mean K level was in the kidney (235 mg/100 g; $P < .05$). The highest level of P was found in the thymus (516 mg/100 g; $P < .05$) and the lowest ($P < .05$) in the heart and tongue (226 and 220 mg/100 g, respectively, $P > .05$). The kidney had the highest Na level (167 mg/100 g; $P < .05$), while the lowest Na levels ($P < .05$) were determined in the spleen, liver and thymus (64.6, 63.5 and 59.6 mg/100 g, respectively, $P > .05$). The level of Mg was highest in the thymus (21.7 mg/100 g; $P < .05$) and lowest in the brain (11.2 mg/100 g; $P < .05$). Numerically, the highest mean Ca level occurred in the testicle (17.6 mg/100 g) and the lowest mean Ca level was in the heart (10.7 mg/100 g; $P < .05$). Furthermore, Zn, Cu and Mn levels were highest in the liver (4.78, 2.62 and 0.21 mg/100 g, respectively; $P < .05$), while Fe and Ni levels were highest in the spleen and testicle (12.8 mg/100 g and 0.046 mg/100 g; $P < .05$, respectively). The brain had numerically the lowest mean Zn level (1.10 mg/100 g), while the thymus had numerically the lowest mean Fe, Cu and Ni levels (0.89, 0.57 and 0.12 mg/100 g, respectively). Finally, the level of Mn was numerically the lowest for the heart (0.015 mg/100 g). Compared to the mineral composition of goat liver, kidney, heart, spleen and brain reported by Webb et al. (2005), the Ca level in the brain, Fe levels in the spleen and kidney, Cu levels in the spleen and liver, and Mn level in the same type of organs in the present study were lower, while K and P levels in the same type of organs were slightly higher. In the present study, compared to the mineral composition of goat kid liver and kidney obtained by Mioč et al. (1998), levels of P and Fe were higher, levels of Mg were slightly higher and levels of Mn were lower for both organs, while the level of Na in the liver was lower. The mineral composition (P, K, Ca, Mg and Na) of goat liver presented by Park (1990) is similar to the results found in the present study.

In conclusion, the present study provides data on the quality of fresh edible by-products from Saanen goat male kids raised under an intensive farming system. Many significant differences were found in the mean values of quality traits among the edible by-products studied. Nevertheless, more studies are necessary to provide better knowledge of the characteristics of edible by-products from Saanen goat male kids, especially the quality of cooked edible by-products intended for human consumption.

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