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ARTICLE

Characterization of Hanwoo Bovine By-products by Means of Yield, Physicochemical and Nutritional Compositions

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Abstract

Though the edible bovine by-products are widely used for human consumption in most countries worldwide but the scientific information regarding the nutritional quality of these by-products is scarce. In the present study, the basic information regarding the yields, physicochemical and nutritional compositions of edible Hanwoo bovine by-products was studied. Our results showed that the yields, physicochemical and nutritional composition widely varied between the by-products examined. The highest pH values were found in rumen, reticulum, omasum and reproductive organ. Heart, liver, kidney and spleen had the lowest CIE L* values and highest CIE a* values. Liver had the highest vitamin A, B2 and niacin contents whereas the highest B1 and B5 contents were found in kidney. The highest Ca content was found in rumen, reticulum, omasum, head and leg while the highest Mn and Fe contents were found in rumen, omasum and spleen, respectively. Liver had the highest Cu content. Total essential amino acids (EAA)/amino acids (AA) ratios ranged between the by-products from 38.37% to 47.41%. Total polyunsaturated fatty acids (PUFA) levels ranged between the by-products from 2.26% to 26.47%, and most by-products showed favorable PUFA/SFA ratios. It is concluded that most of by-products examined are good sources of essential nutrients and these data will be of great importance for promotion of consumption and utilization of beef by-products in future.

Keywords: bovine by-products, color, vitamin, mineral, amino acid, fatty acid contents

Introduction

The edible meat by-products constitute a significant ratio of live weight of an animal for instance; the yields of edible meat by-products vary ranging from 10% to 30% for pork and beef (Nollet and Toldra, 2011). The edible meat by-products comprise a variety of products including internal organs (e.g., heart, lung, liver, spleen and kidney), entrails and other parts such as head, tail and feet etc.

The utilization of the meat by-products considerably depends upon a number of factors such as; culture, religion, earnings and preference etc. In general, however, the edible meat by-products are widely used in many countries in different traditional dishes for instance, sheep liver (Iran), boiled tongue (South America), pork's feet and pork's ears (Spain) and so on (Toldra *et al*., 2012). Especially, all parts of edible meat by-products are salvaged and commonly used as human foods in South Africa, Egypt, Italy, Spain and Asian countries etc, whereas the demand for these meat by-products in USA and Australia is generally lower (Fatma and Mahdey, 2010; Nollet and Toldra, 2011; Pearson and Dutson, 1988). While, a downtrend in consumption of meat by-products in Western Europe has recently been reported (Selmane *et al*., 2008). On the other hand, the consumption of edible meat by-products also varies depending upon animal species for instance; the edible meat by-products of goat is more commonly consumed than cattle's edible offal in some countries such as Indonesia, India, Pakistan and Bangladesh, while the offal of chicken is the most commonly consumed in Japan (Nollet and Toldra, 2011). By these reasons it has led to an unbalance between production and consumption of the meat by-products between animal species in/or between countries. The reasons making the edible meat by-products not being well utilized in some countries could be attributed due to the lack of scientific information to consumers about the nutritional composi-

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tion of these by-products. Therefore, awareness of the physicochemical and nutritional compositions of the edible meat by-products is greatly important to promote the consumption and their utilization in meat processing industry.

More to the point, the world meat consumption has increased, meaning that a considerable amount of the edible meat by-products is produced every day from slaughterhouses however, the utilization of their by-products for human consumption has decreased (Ockerman and Basu, 2004). Therefore, the large amount of meat by-products produced has become a burden to the slaughterhouses in disposing of theme when they are not utilized (Toldra *et al*., 2012). However, this abundant available resource also produces good opportunities for the meat industry and processors to increase economic profitability if these by-products are salvaged and utilized in a suitable way. Moreover, efficient utilization of edible meat by-products is needed in order to support economical and viable meat production systems (Kurt and Zorba, 2007). In fact, some attempts have been made aiming to increase the commercial values of edible meat by-products by using them in various meat products such as; liver pate, liver and blood sausages (Estevez *et al*., 2005; Nollet and Toldra, 2011; Santos *et al*., 2003), and using them as the technical functional ingredients to increase protein level and water binding capacity of food products (Mandal *et al*., 1999). However, the quantity of meat by-products utilized is still much lesser compared with their large amount generated.

Hanwoo cattle, a type of Korean native cattle whose meat is the most preferred by Korean consumers regardless of its approximately doubled price because they believe that Hanwoo beef is fresher and of superior eating quality (Jo *et al*., 2012). Approximately thousands of Hanwoo cattle are slaughtered per year (Livestock and Products Annual, 2013), implying that a considerable amount of bovine by-products is generated every day from the slaughterhouses in the country. Although some edible by-products of Hanwoo cattle (e.g., heart, liver and spleen) are also consumed in Korea however, these by-products generally have low commercial values and the consumed amount is still limited. For the past decades, most studies have only focused on beef muscles of various cattle breeds regarding the physicochemical composition, quality attributes and their utilization is available on internet and textbooks etc. Whereas, the edible meat by-products from cattle are also widely used for human foods however, the scientific information regarding the nutritional quality of these by-products is scarce with limited data available such as the nutrient database of USDA (2011). Furthermore, previous studies only focused on few organs such as; liver, heart and kidney from pork, lamb, buffalo and veal calves (Devatkal *et al*., 2004; Florek *et al*., 2012; Kim, 2011; Kim *et al*., 2008). Therefore, the objective of the present study was to investigate the yield, physicochemical and nutritional compositions of meat by-products from Hanwoo cattle. The findings of our study would be beneficial for promoting consumption and future utilization of edible bovine by-products.

Materials and Methods

Sample preparation

Forty Hanwoo cattle (24 females and 16 males) with their live weights of about 500-550 kg at 30-32 mon of age were obtained from a local farm in Suwon, South Korea. The animals were reared with their mothers until the weaning age at 6-7 mon, then grazed on pastures and fed *ad libitum* with a finishing concentrate diet at feedlot of the farm until slaughter. Animals were transported to an abattoir of the National Institute of Animal Science, Suwon, Korea, where the animals were conventionally slaughtered. After slaughter, their organs including heart, liver, kidney, lung, cecum, esophagus, rumen, reticulum, omasum, abomasums, small intestine, large intestine, spleen, reproductive organ, pancreas and bladder, blood, head and tail were immediately collected and used for the present investigation. The selected internal organs were washed under running tap water to remove adhering blood, food remnants, feces, impurities, trimmed off of visible fats and connective tissues. After draining the water, the offal was weighed to determine yield, then individually packaged in polyethylene bags and transferred to the Meat Laboratory. The offal samples were stored at 2-4°C and used for analyses of color, proximate and nutritional compositions. Each offal sample was analyzed in triplicates.

Color measurement

The color of selected offal samples were determined about 24 h after slaughter using a Minolta Chroma Meter CR-400 (Minolta Camera Co., Ltd., Japan). Color was expressed according to the Commission International de l'Eclairage (CIE) system and reported as CIE L* (lightness), CIE a* (redness), CIE b* (yellowness), chroma and hue. The color was directly determined at five different areas on the surface of each sample.

Proximate composition and calorie

Moisture, protein, fat and ash contents of offal samples were analyzed according to the method of the Association of Official Analytical Chemists (AOAC, 2000); the moisture and fat contents were determined by using a moisture & fat analyzer (SMART Trac, CEM Corp, USA); protein content was determined by using a nitrogen analyzer (Rapid N cube, Germany) and then converted into protein content using the N×6.25 equation (N=nitrogen content obtained from the samples, and 6.25=conversion factor); and ash content was determined by using a microwave ashing oven (MAS 7000, CEM Corp., USA). To determine calorie, the offal sample (50 g each) was homogenized in a blender (HMF 3160S, Hanil Co., Korea), then the homogenized sample was used for measurement of calorie content by using a caloriemeter model 1261 (Parr Instrument, USA). Calories were expressed as cal/g of the sample.

pH measurement

The pH values of by-products were measured in triplicates following the procedure of Bendall (1973) using a portable pH meter (Mettler-Toledo GmbH, Switzerland).

Vitamin content

Vitamins (vitamin A, B1, B2, niacin, B5 and B6) in the bovine by-products were determined by following the procedures of AOAC (2000) using a reversed-phase high performance liquid chromatography (RP-HPLC) (Aglient 1200 series, Aglient, USA).

Mineral content

The mineral contents of the offal were determined by following the method of AOAC (2000). Briefly, 5 grams of each sample was destroyed by dry ashing in a microwave ashing oven for 12 h with a final temperature of 600ºC. The ash content was dissolved in 10 mL of HCl and distilled water (1:1 v/v) solution and was then filtered through Whatman filter paper (No. 6) (AEC Scientific Co., Korea). Minerals including Na (selected wavelength 588.9 nm), K (766.5 nm), Ca (422.7 nm), Mg (285 nm), P (470 nm), Fe (248.3 nm), and Zn (213.9 nm), Mn (279.5 nm) and Cu (324.7 nm) were determined by atomic emission spectrophotometer ICP-OES (Spectro, Boschstr, Germany). A calibration curve was prepared for each element.

Amino acid content

Samples used for amino acid analysis were hydrolyzed with 6 N HCl solution for 24 h at 110°C. The hydrolyzed samples were concentrated at 50ºC and then diluted with 50 mL of 0.2 N sodium citrate buffer (pH 2.2), and finally the samples were filtered through 0.45 μm filters (Millipore Corp., USA). The amino acids were determined by applying the filtrates (30 × L each) to an amino acid analyzer (model 8900A) equipped with an ion-exchange column (4.6×60 mm) (Hitachi, Japan). The separation and detection of amino acids were carried out using the method as described by Spackman *et al*. (1958).

Fatty acid composition

Fatty acid composition was extracted according to the methods of Folch *et al*. (1957) and Morrison and Smith (1964). The fatty acids were analyzed using a gas chromatograph system (Varian star 3600, Varian, Inc., USA) equipped with flame ionization detector and Omegawax 205 fused-silica bond capillary column (30 m × 0.32 mm × 0.25 μm film thickness). The initial and final temperatures of the oven were 140°C and 230ºC, respectively. The injector port and detector temperatures were 250°C and 260°C respectively. The fatty acid profile was expressed as percentages of individual fatty acids identified.

Statistical methods

The data were collected using Microsoft Office Excel 2007 and subjected to statistic analysis using the Statistic Analysis System (SAS) package (2007). The pooled data were analyzed using the General Linear Models (GLM) of the SAS program. Significant differences among by-product types were analyzed by Duncan's Multiple Range test at $p<0.05$.

Results and Discussion

Yield based on live weight (kg) of offal

The yields of Hanwoo bovine by-products are summarized in Table 1. It was observed that the yields widely varied between the by-products. Previous workers (Nollet and Toldra, 2011) reported the average weight of beef liver (5.0 kg), heart (1.4 kg) and kidney (0.5 kg). Similarly Florek *et al*. (2012) reported the average weights of liver (1.34 kg and 3.09 kg), kidney (0.312 kg and 0.587 kg) and heart (0.424 kg and 1.0 kg) for veal calves and suckler beef, respectively. The yields of some by-products (e.g., heart, liver and kidney) in the present study were generally similar the yields reported for cow but higher than the values reported for veal calves and suckler beef as cited above. Additionally, the yields of some by-products (e.g., liver, heart and kidney) in the present study

Table 1. Yield based on live weight of offal of Hanwoo cattle

Offal	Yield (kg)
Live weight	631.67±100.5*
Blood	16.33±3.62
Head	24.8±6.64
Forefoot	5.82±1.14
Hind-foot	5.09±0.79
Tail	0.94±0.2
Heart	2.3±0.41
Liver	6.66±0.89
Kidney	1.02±0.25
Lung	2.9±0.66
Small intestine	3.94±0.75
Cecum	0.37±0.1
Large intestine	1.19±0.49
Rectum	0.71±0.27
Spleen	1.32±0.25
Respiratory	0.8±0.21
Esophagus	0.51±0.17
Rumen	7.77±1.47
Reticulum	1.11±0.26
Omasum	2.77±0.74
Abomasum	1.78±0.5
Pancreas	0.49±0.2
Bladder	0.16±0.03
Duodenum	0.12±0.06
Reproductive organ	1.28±0.45
Breast	0.52±0.23
Gallbladder	3.3±2.28

*Mean±standard error.

were higher than the values reported for lamb and pig (Ockerman and Basu, 2004). Therefore, from our results and previous findings it could be concluded that yields of edible meat by-products differ depending on the type of offal, animal age, live weight and species.

Color characteristics of edible bovine by-products

The color parameters of edible bovine by-products are summarized in Table 2. Offal type significantly ($p<0.05$) affected all color parameters. The highest CIE L* values were found in the intestines, cecum, rectum, pancreas, bladder and reproductive organ, indicating that these by-products have the lightest surfaces. Whereas, spleen had the lowest CIE L* value. Florek *et al*. (2012) reported slightly higher CIE L* value (35.13) for veal calf liver and a lower value (29.15) for suckler bovine liver. Furthermore, heart and lung were redder than the other remaining by-products and their CIE b* values were nearly similar the values reported for beef muscle (Moon *et al*., 2006). Additionally, cecum, rectum, abomasum, pancreas and duodenum had higher CIE b* values than other remaining by-products and these values were similar the values reported for beef muscle of Hanwoo and Angus breeds (Ba *et al*., 2013). The first impression consumers have of any meat product is its color and thus, color may be the most important factor that influences the appearance and attractiveness of meat product to consumers (Faustman and Cassens, 1990). This is the first study to characterize the color characteristics of major bovine by-products and the differences in color could be attributed due to the variations in the chemical compositions such as fat level, protein type, moisture and concentration of pigment between these by-products.

Proximate composition of edible bovine by-products

The proximate compositions of eighteen bovine by-products are shown in Table 3. The pH values were significantly ($p<0.05$) different between the by-products, ranging from 5.80 to 7.12. In general, the parts of digestive tract (e.g., rumen, reticulum, omasum, abomasums, small and large intestines), lung and reproductive organ had higher pH values than other by-products such as heart (5.80) and liver (6.23). Previous workers (Kurt and Zorba, 2007) reported that the pH value (6.54) of bovine kidney was higher than the values (6.21 and 5.88) of liver and heart, respectively. Similarly Florek *et al*. (2012) found that calf kidney had higher pH value (6.53) than liver (6.16) and heart (5.80). The results of the present study were in accordance with those reported for the bovine kidney, liver and heart as cited above. The differences in pH values could be attributed due to the differences in the inherent properties and postmortem glycogen degradation between the by-products (Florek *et al*., 2012; Roach, 2002).

The moisture content varied among the by-products, ranging from 56.12% to 84.64%. Excepted for abomasum which had lower moisture (61.18%), the other remaining by-products from digestive tract (e.g., rumen, reticulum, omasum, abomasums, small and large intestines) contained the most moisture content (above 82%). While the moisture contents ranged between heart, kidney, lung, cecum, spleen, esophagus, duodenum and reproductive organ from 75% to below 80%. Florek *et al*. (2012) reported the higher moisture content of raw suckler beef liver (72.32%), kidney (79.04%) and heart (79.03%). Similarly Devatkal *et al*. (2004) reported higher moisture content (71.92%) in raw buffalo liver.

Among the bovine by-products examined, pancreas and abomasum had the highest fat contents (26.29% and 25.67%, respectively) and other remaining by-products

Table 2. Color parameters of offal of Hanwoo cattle

Offal	CIE L*	CIE a*	CIE b*	Chroma	Hue
Heart	30.66±2.71*	17.14±2.21	4.93±1.24	22.51±2.03	17.50±4.17
Liver	32.36±3.86	10.11±2.03	2.12±1.34	13.09±2.07	12.15±6.30
Kidney	31.20±3.33	13.23±1.50	5.51±2.24	18.54±1.79	24.53±6.31
Lung	47.16±8.40	20.49±4.53	6.29±3.22	25.29±5.89	20.05±10.85
Small intestine	52.78±4.19	4.68±3.53	7.02±2.32	10.47±4.12	61.09±20.35
Cecum	56.98±4.76	6.05±2.64	9.77±2.88	13.72±3.53	62.30±10.97
large intestine	57.00±4.41	4.36±2.71	7.65±2.57	10.65±3.51	63.91±12.68
Rectum	59.17±4.08	8.71±2.95	9.78±2.08	15.42±2.84	52.03±9.90
Spleen	22.09±2.31	10.38±2.72	3.66±1.43	15.20±3.29	21.63±4.70
Esophagus	39.85±9.84	16.23±4.28	5.08±2.24	20.64±6.04	19.03±6.54
Rumen	25.04±12.16	1.60±1.25	2.89±1.87	4.81±2.07	63.36±9.30
Reticulum	33.54±10.01	2.18±1.60	4.25±2.00	6.71±3.03	65.15±9.71
Omasum	32.70±5.10	1.68±0.81	3.79±1.33	5.71±1.56	66.81±7.63
Abomasum	47.48±6.31	15.81±3.17	8.70±3.58	21.22±3.12	31.59±12.15
Pancreas	57.01±4.68	14.82±3.45	9.49±3.06	20.16±3.97	35.79±8.62
Bladder	58.81±6.51	9.49±4.09	6.43±3.84	13.54±4.71	36.08±16.62
Duodenum	48.11±4.97	8.75±3.47	8.62±2.96	14.94±4.10	47.49±13.03
Reproductive organ	68.02±5.87	9.34±4.19	5.90±3.33	11.81±5.06	32.97±13.39
Offal type effect[1)]	***	***	**	**	**

*Mean±standard error.
[1)]Significance of offal type effect; **p<0.01; ***p<0.001.

Table 3. Proximate composition of offal of Hanwoo cattle

Offal	pH	Moisture (%)	Fat (%)	Protein (%)	Ash (%)	Calorie (cal/g)
Heart	5.80±0.24*	75.49±0.93	3.72±0.75	18.62±0.53	0.60±0.29	1909.2±196.2
Liver	6.23±0.12	69.21±8.53	3.15±0.71	18.59±0.88	1.18±0.04	1,957.30±257.32
Kidney	6.48±0.18	78.10±1.27	2.91±0.77	16.03±0.91	0.87±0.10	1,326.90±107.09
Lung	6.60±0.15	77.35±0.65	2.68±0.66	17.64±0.72	0.44±0.44	1,623.10±90.41
Small intestine	6.56±0.11	82.91±3.51	4.94±3.28	10.19±1.10	0.53±0.02	1,273.10±333.60
Cecum	6.76±0.20	75.55±7.06	10.12±6.93	12.91±1.26	0.46±0.08	2,196.60±1250.5
Large intestine	6.61±0.14	82.98±1.02	3.34±1.21	13.28±0.92	0.48±0.06	1,276.70±157.63
Rectum	6.58±0.14	82.26±1.23	2.66±1.29	14.24±1.21	0.63±0.26	1,277.56±169.70
Spleen	6.27±0.32	77.76±0.79	1.4±0.83	18.21±0.61	1.15±0.09	1,465.10±114.70
Esophagus	6.09±0.36	75.67±2.40	7.58±2.42	17.89±1.11	0.74±0.16	2,103.00±302.46
Rumen	7.12±0.20	83.41±2.12	2.25±1.12	16.08±0.85	0.41±0.08	1,478.30±263.58
Reticulum	6.92±0.20	83.13±1.66	3.11±1.56	15.32±1.15	0.45±0.07	1,566.70±224.02
Omasum	6.90±0.19	84.64±1.49	1.53±1.41	13.90±1.80	0.46±0.07	1,542.70±318.76
Abomasum	6.61±0.22	62.18±7.92	25.67±8.70	9.78±1.17i	0.43±0.05	3,457.40±111.16
Pancreas	6.30±0.20	56.21±9.73	26.29±11.01	13.38±1.71	0.87±0.14	3,224.60±758.38
Bladder	6.54±0.16	81.53±1.23	0.39±0.44	22.23±2.26	0.51±0.06	938.80±391.42
Duodenum	6.48±0.02	79.98±2.31	5.43±1.31	21.31±1.77	0.30±0.10	1,924.10±174.78
Reproductive organ	6.84±0.23	77.93±2.36	1.16±0.90	21.24±5.02	0.22±0.06	1,536.50±95.84
Offal type effect[1)]	*	**	***	***	**	***

*Mean±standard error.
[1)]Significance of offal type effect; *p<0.05; **p<0.01; ***p<0.001.

had lower fat contents ranging from 0.39% to 10.12%. The fat contents in heart, kidney and liver in the present study were in accordance with those reported for beef offal (Ockerman and Basu, 2004) but slightly higher than the values reported for suckler beef (Florek *et al*., 2012). Hoffman *et al*. (2013) reported relatively higher fat contents in cooked heart (16.4%), kidney (6.2%), liver (9.7%), lung (4.6%) and spleen (4.3%) of sheep breed. The differences in the fat contents could be due to the animal age and species differences. On the other hand, the fat contents of most by-products were lower than the fat contents (5.86-25.97%) of raw muscle tissues of the same cattle breed (Ba *et al*., 2013; Moon *et al*., 2006) and Japanese black cattle (23.74-41.15%) (Okumura *et al*., 2012). Daily

fat intake is important for human health because the fat not only contributes to energy intake but also helps vitamin absorbance; however, a high daily fat intake has been associated with some diseases such as; obesity and cardiovascular disease (Bray *et al*., 2004). In the present study, the fat levels of these by-products are generally similar or even lower than the fat contents of muscle tissues of the same and other cattle breeds.

Protein content widely varied among the bovine by-products; particularly, bladder, duodenum and reproductive organ had the highest protein contents (22.23%, 21.31% and 21.24%, respectively). The protein levels of these three by-products were similar the levels of raw beef loin (21%) and pork loin (22.2%) (Pereira and Vicente, 2013). The protein contents of heart (18.62%), liver (18.59%) and spleen (18.21%) were in accordance with those reported for bovine offal (Ockerman and Basu, 2004) and comparable to the protein contents of raw pork chops (17.3%) and duck meat (19.3%). Earlier workers (Hoffman *et al*., 2013) reported lower protein contents (13.5% and 15.2%, respectively) for cooked heart of Merino and Dorper sheep breeds. The protein contents of other remaining by-products were lower, ranging from 9.78% to 17.89% in the present study.

Liver and spleen had higher ash contents than other remaining by-products, and the ash contents of these two organs were comparable to the value reported for rabbit meat (Zotte and Szendro, 2011). Higher ash contents have been reported for the veal calf and sheep livers, kidneys, hearts, lungs and spleens (Florek *et al*., 2012; Hoffman *et al*., 2013). The abomasum and pancreas had the highest calories in comparison to the other remaining by-products; this could be attributed due to their high fat contents. The calories of heart, liver, lung, spleen and kidney in the present study were generally higher than the values reported by other authors (Honikel, 2011) for bovine offal. The recommended daily allowance for an adult is 60 g protein, 90 g dietary fat and 2500 kcal (Honikel, 2011) therefore for example; a consuming 100 g of bovine liver would supply 31% of protein, 3.5% fat and 7.6% total energy.

Vitamin content of edible bovine by-products

Our results showed that the vitamin contents varied considerably among the by-products examined (Table 4). Amongst, liver had the highest vitamin A content (5,027.08 μg RE 100/g) whereas the lowest was found in spleen (6.95 μg RE/100g). The results of the present study were in accordance with those reported for the liver, heart and kidney of similar species (Honikel, 2011) but lower than the values reported for pork, veal and lamb offal (Kim, 2011). When compared to the vitamin A content (5 μg RE 100/g) of beef muscle tissues (Honikel, 2011), all bovine by-products examined had considerably higher vitamin A contents. Similarly heart, liver, kidney, abomasum and pancreas contained the most vitamin B1 contents, and these values were similar the values reported by Ockerman and Basu (2004) for bovine offal. How-

Table 4. Vitamin content of edible offal of Hanwoo cattle

Offal	Vitamin A (μg RE/100g)	Vitamin B1 (mg/100g)	Vitamin B2 (mg/100g)	Niacin (mg/100g)	Vitamin B5 (mg/100g)	Vitamin B6 (mg/100g)
Heart	12.49±2.69*	0.14±0.06	0.07±0.02	7.46±1.06	0.49±0.11	0.03±0.01
Liver	5,027.08±746.56	0.18±0.04	0.41±0.12	12.24±0.42	0.98±0.82	0.03±0.01
Kidney	53.13±44.61	0.25±0.05	0.38±0.19	7.14±0.80	1.03±0.65	0.04±0.03
Lung	11.50±60	0.06±0.01	0.05±0.01	4.00±0.09	0.24±0.04	0.01±0.01
Small intestine	20.49±15.48	0.01±0.01	0.05±0.02	1.40±0.56	0.16±0.09	ND
Cecum	25.57±15.66	0.03±0.01	0.03±0.01	2.34±0.30	0.3±0.06	ND
Large intestine	14.24±10.42	0.03±0.01	0.04±0.01	2.28±0.58	0.27±0.06	ND
Rectum	19.49±18.53	0.03±0.01	0.03±0.01	2.38±0.33	0.25±0.13	ND
Spleen	6.95±5.98	0.09±0.01	0.07±0.02	4.76±0.39	0.37±0.07	ND
Rumen	28.97±24.38	0.03±0	0.07±0.02	1.84±0.53	0.28±0.04	ND
Reticulum	15.09±9.44	0.03±0.01	0.05±0.01	1.87±0.41	0.3±0.06	ND
Omasum	38.98±46.5	0.02±0.01	0.08±0.02	1.18±0.49	0.35±0.43	ND
Abomasum	34.1±34.1	0.19±0.05	0.07±0.02	2.09±0.87	0.39±0.44	ND
Pancreas	45.52±37.85	0.12±0.12	0.05±0.02	3.03±0.62	0.29±0.06	ND
Duodenum	22.76±26.83	0.01±0	0.02±0.01	1.02±0.36	0.2±0.08	ND
Offal type effect[1)]	***	***	***	**	*	***

*Mean±standard error.
ND: not detectable.
[1)]Significance of offal type effect; *p<0.05; **p<0.01; ***p<0.001.

ever, the concentrations of vitamin B1 in heart, liver, kidney, abomasum and pancreas were higher than the values (0.07-1.0 mg/100 g and 0.06-012 mg /100 g, respectively) reported for beef and chicken muscle tissues (Zotte and Szendro, 2011). Additionally, the vitamin B2 contents of liver (0.41 mg/100 g) and kidney (0.38 mg/100 g) in the present study were higher than those in muscle tissues of pork (0.10-0.18 mg/100 g), beef (0.11-0.24 mg/100 g), veal (0.14-0.26 mg/100 g), chicken (0.12-0.22 mg/100 g) and rabbit (0.09-0.12 mg/100 g) reported in literature (Zotte and Szendro, 2011). Liver had the highest niacin content (12.24 mg/100 g), heart and kidney had similar niacin contents (7.46 mg/100 g and 7.14 mg/100 g, respectively). The concentrations of niacin in these two by-products were similar to the values reported for bovine offal (Ockerman and Basu, 2004) but higher than the value (4.2-5.3 mg/100 g) reported for beef muscle tissue (Zotte and Szendro, 2011). Vitamin B6 was only found in heart, liver, kidney and lung at low concentrations. It has long been recognized that vitamins are essential compounds that maintain the normal function and metabolic reactions in the body because most vitamins cannot be made in body, so they must be supplied from foods. In the present study, the amounts of most of vitamins in the bovine by-products were considerably higher than those in muscle tissues. This is in agreement with the previous observations of Kim (2011) which indicated that internal organs have more vitamin contents than muscle tissues. Moreover, the outcome of our analysis showed that the concentrations of vitamins B in almost bovine by-products were comparable to grain, cereal-grain food and soy-products, which are well recognized as the richest sources of vitamins B (Lebiedzinska and Szefer, 2006).

Mineral content of edible bovine by-products

The concentrations of minerals in the Hanwoo bovine by-products are presented in Table 5. Our results depict that the concentrations of macroelements such as calcium (Ca), phosphorous (P), potassium (K), sodium (Na) and magnesium (Mg) vary between the by-products in which the K contents in these by-products were higher, followed by P, Na, Ca and Mg contents. The concentrations of macroelements in heart, liver, kidney and pancreas were similar to values reported by Ockerman and Basu (2004) and Florek *et al*. (2012) for bovine offal. Especially, the Ca contents in digestive tract such as; rumen (179 mg/kg), reticulum (137 mg/kg) and omasum (140 mg/kg), were higher than those in the other remaining by-products in the present study and higher than the Ca contents (87 mg/kg, 19.9 mg/kg and 60 mg/kg) reported for muscle tissues of rabbit, rhea and beef, respectively (Hermida *et al*., 2006; Ramos *et al*., 2012; Honikel, 2011). Furthermore, the amounts of Na in liver (665.15 mg/kg), small intestine (500.95 mg/kg), rumen (621.45 mg/kg), reticulum (628.26 mg/kg), omasum (623.97 mg/kg) and abomasums (541.89 mg/kg) were lower in comparison with the breast chicken (770 mg/kg) and duck meat (920 mg/kg) (Pereira and Vicente, 2013).

Iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and chromium (Cr) are trace elements that are vital for maintaining human health, insufficient intake of these trace minerals can cause symptoms of nutritional deficiency (Tapiero and Tew, 2003). Amongst, Fe is one of the vital minerals needed for the optimum function of blood; iron deficiency causes anemia, especially in pregnant women and children (Benoist, 2001). The outcome of our analysis showed that spleen had the highest Fe content (1,233.46 mg/kg). Furthermore, the Fe contents of liver (66.71 mg/kg), kidney (68.23 mg/kg) and heart (58.88 mg/kg) in the present study were higher than the values reported for the liver, heart and kidney of veal calves and suckler beef (Florek *et al*., 2012). These contrasting results of Fe contents may be due the animal age differences. When compared to the Fe levels in breast chicken (5 mg/kg), beef steaks (14 mg/kg), pork chop (13 mg/kg), duck meat (24 mg/kg) and mutton meat (17 mg/kg) reported by Pereira and Vicente (2013), all bovine by-products had considerably higher amounts of Fe content. Moreover, the iron in spleen, liver and other meat by-products is heme iron; its absorption into the intestinal lumen is several times greater than non-heme iron present in other foods (Hallberg and Hulthen, 2000; Simpson and McKie, 2009).

Mn is an essential mineral involved the growth, metabolism and enzymatic defense systems of the body (Aschner and Aschner, 2005). Our results show that the Mn contents in rumen (8.81 mg/kg) and omasum (8.03 mg/kg) were higher than those in other remaining by-products and also much higher than the content in the other meat by-products (e.g., liver, heart, kidney etc) of pork and lamb origins (Ockerman and Basu, 2004). Additionally, the levels of Mn contents in the rumen and omasum were higher than the values reported for the muscle tissues of pork, breast turkey and pork loin (Pereira and Vicente, 2013). From these results it is concluded that bovine rumen and omasum are rich sources of Mn content. Comparison of Cu contents between the offals in the present study showed the highest amount (122.36 mg/ kg) of Cu in liver. The amount of Cu in the liver was consid-

Table 5. Mineral content of edible offal of Hanwoo cattle

Offal	Ca (mg/kg)	P (mg/kg)	Na (mg/kg)	K (mg/kg)	Mg (mg/kg)	Mn (mg/kg)	Fe (mg/kg)	Cu (mg/kg)	Zn (mg/kg)
Heart	53.66 ±7.92*	2170.83 ±65.67	905.68 ±91.85	2870.84 ±298.6	198.59 ±17.3	0.92 ±0.35	58.88 ±5.37	2.87 ±0.37	20.44 ±1.12
Liver	62.03 ±8.74	2903 ±144.54	665.15 ±60.03	3066.66 ±163.8	167.84 ±18.3	3.05 ±0.29	66.71 ±9.09	122.36 ±24.5	36.64 ±3.45
Kidney	86.7 ±6.69	2151.85 ±212.3	1888.16 ±176.31	2018.53 ±208.2	138.07 ±7.7	1.24 ±0.14	68.23 ±10.85	3.72 ±0.57	23.4 ±3.24
Lung	93.99 ±15.6	2153.63 ±100.83	1600.69 ±61.98	2099.90 ±130.8	104.75 ±4.29	0.29 ±0.08	100.77 ±12.5	1.6 ±0.14	17.55 ±0.86
Small intestine	86.17 ±8.33	1201.14 ±247.78	500.95 ±162.5	932.51 ±257.70	81.81 ±12.08	0.67 ±0.25	18.42 ±3.27	1.12 ±0.37	11.68 ±2.08
Cecum	91.13 ±25.49	1167.3 ±337.59	920.82 ±212.18	1410.47 ±151.31	82.94 ±14.8	0.58 ±0.28	8.61 ±2.12	1.22 ±0.27	16.56 ±9.67
Large intestine	95.92 ±18.63	1285.5 ±172.02	737.57 ±129.89	1464.74 ±281.91	90.42 ±7.99	0.58 ±0.11	12.25 ±6.15	2.54 ±1.15	14.37 ±0.96
Rectum	88.37 ±9.47	1140.7 9±192.66	992.13 ±122.88	1625.44 ±185.5	87.5 ±6.25	0.5 ±0.07	7.43 ±1.28	2.18 ±0.69	17.91 ±1.41
Spleen	57.25 ±6.48	2519.48 ±225.22	823.16 ±46.36	3430.85 ±204.61	159.2 ±8.71	0.33 ±0.08	1233.46 ±56	2.01 ±1.11	26.32 ±1.83
Esophagus	83.23 ±9.91	1264.46 ±79.26	957.77 ±47.6	1673.32 ±146.74	130.1 ±8.49	0.48 ±0.28	15.91 ±2.82	1.69 ±0.5	28.71 ±2.33
Rumen	179.18 ±10.6	926.21 ±113.18	621.45 ±103.27	879.30 ±78.68	115.39 ±33.85	8.81 ±4.31	94.87 ±19.93	1.9 ±0.54	15.98 ±3.34
Reticulum	137.95 ±44.24	924.23 ±94.28	628.26 ±93.79	1008.70 ±85.05	92.51 ±15.15	3.3 ±1.91	37.87 ±16.97	1.66 ±0.4	16.71 ±1.36
Omasum	140.04 ±38.34	860.17 ±51.82	623.97 ±127.29	989.45 ±193.81	89.81 ±7.35	8.03 ±4.7	52.84 ±13.29	1.26 ±0.3	20.95 ±2.26
Abomasum	75.47 ±7.94	1018.81 ±138.3	541.89 ±106.7	1005.11 ±196.72	82.37 ±13.6	1.17 ±0.35	30.73 ±7.88	1.38 ±0.31	9.71 ±1.36
Pancreas	130.4 ±32.36	3038.86 ±447.04	730.85 ±111.76	2533.42 ±268.15	159.97 ±17.94	1.69 ±0.32	45.17 ±14.68	1.65 ±0.57	44.03 ±8.52
Reproductive organ	77.33 ±8.27	659.61 ±64.03	1410.1 ±138.78	818.61 ±93.97	55.89 ±6.65	0.32 ±0.14	7.66 ±1.02	1.34 ±0.19	12.46 ±1.91
Tongue	76.94 ±13.2	1277.17 ±81.17	692.45 ±117.77	1509.28 ±133.25	149.66 ±11.62	0.28 ±0.23	29.43 ±2.32	1.67 ±0.27	42.32 ±4.29
Head	222.28 ±86.9	664.45 ±64.90	638.91 ±297.57	436.5 ±56.25	95.34 ±11.15	0.23 ±0.04	19.62 ±3.64	2.42 ±0.63	21.33 ±3.39
Leg	252.27 ±69.42	230.45 ±39.92	378.2 ±46.84	106.73 ±34.61	52.11 ±10.46	0.15 ±0.15	5.5 ±1.28	0.83 ±0.17	4.62 ±0.98
Tail	86.6 ±10.53	989.1 ±88.75	857.53 ±158.73	1485.33 ±202.09	109.88 ±10.23	0.15 ±0.06	19.11 ±2.21	1.28 ±0.2	30.84 ±3.09
Offal type effect[1)]	**	***	***	***	***	***	***	***	**

*Mean±standard error.
[1)]Significance of offal type effect; **p<0.01; ***p<0.001.

erably higher than the values reported for pork liver (6.8 mg/kg) and buffalo liver (5.4 mg/kg) (Devatkal *et al*., 2004; Ockerman and Basu, 2004). Furthermore, with exceptions of leg and small intestine, all by-products had higher amounts of Cu content than muscle tissues of beef, rabbit and rhea (Hermida *et al*., 2006; Honike, 2011; Ramos *et al*., 2012). Similarly, the Zn contents also varied among the by-products determined with higher Zn levels were found in pancreas, tongue, liver and tail, and these levels were comparable to the reported value (37 mg/kg) of muscle tissue of beef (Honike, 2011).

Amino acid content of edible bovine by-products

The amino acid (AA) contents of beef by-products are shown in Table 6. Our results depict that the levels of both essential amino acids (EAA) and non-essential amino acids (NE) show a large variation between the by-products examined. Eight major EAAs including methionine,

Table 6. Amino acid content of edible offal of Hanwoo cattle

Items	Offal																SEM[1)]	Offal type Effect
	Heart	Liver	Kidney	Lung	Small intestine	Cecum	Large intestine	Rectum	Spleen	Esopha-gus	Rumen	Reticu-lum	Omasum	Aboma-sum	Pancreas	Tongue		
Essential amino acids (E)																		
MET	0.38	0.32	0.26	0.25	0.17	0.24	0.22	0.24	0.34	0.39	0.3	0.28	0.31	0.2	0.26	0.49	0.07	ns
THR	0.85	0.84	0.72	0.65	0.42	0.51	0.53	0.52	0.76	0.7	0.57	0.54	0.56	0.37	0.61	0.97	0.06	*
VAL	0.79	0.84	0.72	0.82	0.4	0.5	0.49	0.58	0.88	0.68	0.57	0.55	0.58	0.38	0.64	0.9	0.05	*
LEU	1.66	1.78	1.39	1.37	0.7	0.87	0.87	0.86	1.44	1.27	1.04	1.0	1.05	0.65	1.02	1.79	0.06	**
I-LE	0.69	0.66	0.54	0.46	0.31	0.38	0.39	0.4	0.51	0.58	0.46	0.45	0.47	0.28	0.47	0.82	0.04	*
LYS	1.53	1.42	1.15	1.14	0.8	0.95	0.94	0.91	1.38	1.45	1.07	1.1	1.09	0.61	0.96	1.84	0.02	*
PHE	0.76	1.01	0.78	0.8	0.41	0.5	0.51	0.53	0.88	0.74	0.6	0.59	0.59	0.36	0.54	0.92	0.03	*
HIS	0.5	0.65	0.62	0.6	0.41	0.41	0.44	0.53	0.72	0.61	0.51	0.34	0.35	0.21	0.32	0.58	0.04	*
ΣE	7.16	7.52	6.18	6.09	3.62	4.36	4.34	4.57	6.91	6.42	5.12	4.85	5.0	3.06	4.82	8.99	0.58	**
No essential amino acids (NE)																		
TYR	0.59	0.66	0.55	0.5	0.29	0.35	0.36	0.37	0.56	0.5	0.42	0.39	0.42	0.26	0.45	0.68	0.03	**
SER	0.79	0.86	0.76	0.74	0.46	0.57	0.63	0.59	0.81	0.75	0.68	0.63	0.68	0.41	0.7	0.91	0.02	ns
GLU	2.93	2.24	1.86	1.85	1.24	1.96	1.99	1.76	2.16	2.44	1.95	1.83	1.92	0.97	1.42	3.26	0.02	*
GLY	0.88	0.934	0.96	1.57	0.87	1.29	1.22	1.33	1.06	1.54	1.45	1.32	1.44	0.81	0.83	1.51	0.02	ns
ALA	1.21	1.2	0.97	1.26	0.71	0.85	0.84	0.83	1.12	1.27	1.0	0.87	0.93	0.58	0.74	1.38	0.05	ns
ASP	1.67	1.68	1.37	1.31	0.8	1.01	1.02	1.04	1.53	1.43	1.16	1.11	1.17	0.7	1.18	1.96	0.14	ns
CYS	0.22	0.29	0.26	0.23	0.13	0.16	0.16	0.18	0.24	0.2	0.18	0.18	0.2	0.13	0.24	0.22	0.03	ns
ARG	1.1	1.02	0.89	0.96	0.66	0.83	0.91	0.99	1.1	1.07	0.97	0.95	1.03	0.6	0.72	1.34	0.05	*
PRO	0.8	0.85	0.79	0.97	0.63	0.86	0.86	0.93	0.79	1.05	0.99	0.88	0.93	0.55	0.62	1.08	0.02	ns
ΣNE	9.60	9.074	7.86	8.89	5.5	7.53	7.63	7.65	8.81	9.75	8.38	7.77	8.3	4.75	6.45	11.66	1.03	*
ΣAA	17.4	17.25	14.59	15.48	9.41	12.24	12.38	12.59	16.28	16.67	13.92	13.01	13.72	8.07	11.72	20.65	2.16	*
E/NE	0.79	0.9	0.86	0.74	0.71	0.63	0.62	0.65	0.85	0.65	0.66	0.67	0.65	0.7	0.82	0.77	0.11	*
E/AA	44.7	47.41	46.13	42.57	41.55	38.48	38.37	39.23	45.88	41.51	39.79	40.27	39.50	41.14	44.97	43.54	4.28	*

Results expressed as amino acid percentage composition.

[1)]Standard error.

[2)]Significance of offal type effect; *$p<0.05$; **$p<0.01$.

ΣE, total essential amino acid.

ΣNE, total non- essential amino acid.

ΣAA, total amino acid.

E/NE, essential to non-essential amino acid ratio.

E/AA, essential amino acid to total amino acid ratio.

threonine, valine, isoleucine, leucine, phynylalanine, lysine and histidine were found in all by-products. Heart, liver, spleen and kidney had the higher total EAAs levels than other remaining by-products. The total EAA/AA ratio (47.41%) in liver in the present study was slightly higher than the value (42%) reported by Kim *et al*. (2008) for fresh pork liver. Noticeably, it was observed that the EAA/NE ratios in most by-products in the present study were similar the values (0.81-0.85) reported for various muscle types of foal meat. Anderson (1988) also reported that pork by-products contain varying levels of amino acids and the levels of the essential amino acids were nearly similar to that of muscle tissues.

The EAAs are very important compositions because they cannot be produced by the body and must be supplied in the diet. Without these essential amino acids, the body is unable to function normally; also the presence of amino acids enables vitamins and minerals to perform all their physiological functions (Wu, 2010). Edible meat by-products have been found to be a source of important nutrients like essential amino acids and among them proteins of the internal organs have high biological value (Savaran and Pavlava, 1980) with a balanced EAA content similar to that of muscle proteins (Aristoy and Toldra, 2011). Furthermore, earlier workers (Aristoy and Toldra, 2011) also reported that the levels of EAAs in meat by-products are not remarkably diminished after cooking or heating treatment due to the low-reducing sugar content of these by-products does not cause secondary degradation reactions such as the Maillard reaction. From our observations it can be concluded that the by-products examined are good sources of EAAs. Additionally, we also assume that the differences in levels and quality of amino acid contents may be attributed due to the differences in protein types (e.g., collagen, myofibril protein etc) between the by-products.

Fatty acid content of edible bovine by-products

The fatty acid composition of different by-products is shown in Table 7. Offal type significantly ($p<0.05$) affected the fatty acid contents. Our results show that palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1n-9) and linoleic acid (C18:2n-6) were the most dominant fatty acids found in all beef by-products. These results are in agreement with the observations of Florek *et al*. (2012) that the C16:0, C18:0, C18:1n-9 and C18:2n-6 were the main fatty acids present in the liver, heart and kidney of veal calves and suckler beef. Lung contains the most C16 :0 content (34.52%) while abomasums contains the most C18:0 (25.12%). The levels of C18:1n-9 content ranged between by-products from 21.69% to 49.44% whiles the C18:2n-6 contents ranged between by-products from 1.93% to 14.48%. Florek *et al*. (2012) reported the C18:1n-9 and C18:2n-6 levels in liver (21.38% and 10.19 %), kidney (27.53% and 9.62%) and heart (24.98% and 20.41%) for the veal calves and suckler beef, respectively. Similarly, Hoffman *et al*. (2013) reported the levels of C18:1n-9 and C18:2n-6 contents ranged between the sheep by-products from 22.9% to 42.0% and from 0.7% to 12.8%, respectively. The C18:1n-9, C18:2n-6 and linolenic acid (C18: 3n-3) are the most dominant mono- and polyunsaturated fatty acids present in muscle tissues. Noticeably, the levels of these three fatty acids in most beef by-products in the present study were similar or even higher than the values reported for the muscle tissues of beef and pork (Alonso *et al*., 2012; Ba *et al*., 2013; Costa *et al*., 2008; Mas *et al*., 2011). Total saturated fatty acids (SFA), unsaturated fatty acids (UFA), polyunsaturated fatty acids (PUFA) levels ranged between the by-products from 36.21% to 60.08%, 39.19% to 63.79%, and 2.26% to 26.47%, respectively in the present study. Hoffman *et al*. (2013) reported higher total SFA levels (68.2-70.0%) and lower total PUFA levels (1.8-7.3%) in sheep heart. Previous studies have reported the total SFA levels in *longissimus dorsi* muscle of Hanwoo and Angus cattle breeds ranged from 36.68% to 45.52% (Ba *et al*., 2013), from 36.1% to 39.5% in foal meat (Sarries *et al*., 2006) and from 36.46 and 37.2% in pork *longissimus thoracis* (Mas *et al*., 2011). When compared to the total SFA levels in muscle tissues of different species as cited above, most by-products had similar SFA levels. Furthermore, total PUFA levels in most by-products examined were higher than the values (2.65-3.87%) reported for beef *longissimus dorsi* muscle (Ba *et al*., 2013; Okumura *et al*., 2012). The PUFA/SFA ratios in heart (0.52), liver (0.51) and spleen (0.5) were higher in comparison with other remaining by-products; and these values were almost equal to the values reported for muscle tissues of other species (Alonso *et al*., 2012; Mas *et al*., 2011; Sarries *et al*., 2006). Hoffman *et al*. (2013) reported lower PUFA/SFA ratios in sheep heart (0.00-0.1) and spleen (0.3).

It was reported that an excessive intake of SFAs may result in a high risk of cardiovascular disease and obesity (Siri-Tarino *et al*., 2010). As the recommendations of Food and Agriculture Organization (FAO) and World Health Organization (WHO) for adult humans as follows; intakes of total fat less than 10% SFA, 15-20% MUFA and 6-11% PUFA (Burlingame *et al*., 2009) therefore reducing

Table 7. Fatty acid content of edible offal of Hanwoo cattle

Fatty acid	Offal																SEM[1)]	Offal type effect[2)]
	Heart	Liver	Kidney	Lung	Small intestine	Cecum	Large intestine	Rectum	Spleen	Esopha-gus	Rumen	Reticu-lum	Omasum	Aboma-sum	Pancreas	Bladder		
C14:0	1.85	1.23	3.13	2.89	3.44	2.89	2.98	3.45	1.44	2.71	3.64	3.35	3.7	3.29	2.51	3.34	0.81	*
C16:0	21.94	21.74	29.61	34.52	26.68	25.45	22.15	20.8	27.46	24.85	23.65	25.5	27.7	32.41	27.04	27.57	3.78	*
C16:1n7	1.27	1.48	1.04	1.45	1.86	2.31	2.91	4.42	1.01	2.53	2.7	2.28	2.21	1.55	1.3	2.65	0.76	*
C18:0	20.65	28.79	23.17	16.92	19.35	17.58	13.02	11.93	22.4	14.77	13.2	15.89	15.38	25.12	23.25	15.2	4.14	*
C18:1n7	0.17	0.07	0.14	0.11	0.25	0.09	0.12	0.11	0.08	0.07	0.094	0.12	0.09	0.09	0.13	0.11	0.16	**
C18:1n9	31.87	20.13	24.45	31.91	36.26	46.98	45.21	48.16	21.69	49.44	43.34	39.76	37.03	34.97	42.59	35.98	6.08	**
C18:2n6	14.48	13.41	9.91	4.84	7.01	2.74	7.44	6.19	8.55	3.83	8.2	7.88	8.83	1.93	2.31	8.31	2.50	**
C18:3n3	0.28	0.41	0.22	0.12	0.16	0.12	0.17	0.15	0.1	0.21	0.17	0.16	0.14	0.11	0.09	0.18	0.08	*
C18:3n6	0.11	0.28	0.11	0.07	0.1	0.06	0.07	0.05	0.09	0.06	0.09	0.08	0.07	0.07	0.08	0.06	0.04	**
C20:1n9	0.15	0.08	0.12	0.18	0.13	0.19	0.204	0.32	0.2	0.32	0.46	0.39	0.69	0.1	0.18	0.43	0.10	*
C20:4n6	7.01	10.91	10.38	7.01	7.27	0.33	5.71	4.27	16.66	0.39	4.42	4.71	4.15	0.15	0.52	6.01	2.68	***
C22:4n6	0.2	3.26	0.19	0.6	0.17	0.31	0.21	ND	1.21	0.07	ND	0.13	ND	ND	0.05	0.87	0.25	***
SFA	44.44	51.75	55.91	54.33	49.47	45.92	38.14	36.21	51.3	42.33	40.48	44.7	46.78	60.82	52.8	46.11	7.06	*
UFA	55.56	48.25	44.092	45.67	50.53	54.08	61.86	63.79	48.7	57.67	59.52	55.27	53.22	39.18	47.2	53.89	7.06	*
MUFA	33.59	21.78	25.88	33.77	38.68	49.81	48.45	53.13	23.11	52.67	46.66	42.64	40.07	36.92	44.2	39.29	6.01	*
PUFA	21.9	26.47	18.22	11.9	11.85	4.27	13.41	10.67	25.59	5.0	12.85	12.64	13.14	2.26	3.0	14.6	6.34	**
n3	0.33	0.6	0.23	0.12	0.16	0.12	0.17	0.15	0.11	0.21	0.17	0.16	0.14	0.11	0.09	0.18	0.146	*
n6	21.64	25.87	17.98	11.77	11.69	4.15	13.23	10.51	25.48	4.79	12.7	12.47	13.04	2.15	2.91	14.45	6.31	**
n6/n3	97.6	71.9	77.573	107.52	66.74	38.41	76.87	85.13	303.89	23.25	75.5	77.055	95.61	21.85	33.04	86.96	74.4	**
MFA/SFA	0.78	0.42	0.479	0.64	0.83	1.17	1.32	1.53	0.45	1.29	1.56	1.0	0.89	0.68	0.85	0.87	0.18	*
PUFA/SFA	0.52	0.51	0.36	0.22	0.27	0.11	0.37	0.31	0.5	0.13	0.32	0.32	0.29	0.04	0.06	0.32	0.15	**

Results expressed as fatty acid percentage composition (percent by weight of total fatty acids).

[1)] Standard error of measurement.

[2)] Significance of offal type effect; *p<0.05; **p<0.01; ***p<0.001.

ND: not detectable.

the intake of SFAs and increasing the intake of PUFAs are strongly encouraged. Also, the recommendations for the PUFA/SFA ratio for the healthy diet as a whole should be 0.40 or higher, while the ratio of *n*-6/*n*-3 fatty acids should be 4.0 or lower (Department of Health 1994). According to the outcome of the present study, the PUFA/SFA ratios in heart, liver and spleen were above the recommended value of 0.4 while the other remaining by-products have the PUFA/SFA ratios almost equal to the recommended value of 0.4. By contrast, the *n*-6/*n*-3 ratios in all by-products examined were above the recommended values of less than 4.0 in the present study. Similar to our results, a great number of studies also found that the *n*-6/*n*-3 ratios in muscle tissues of beef and pork were generally higher than the recommended values of less than 4.0 (Aloso *et al*., 2011; Ba *et al*., 2013; Brugiapaglia *et al*., 2014; Mas *et al*., 2011; Wood *et al*., 2003).

Conclusion

This paper studied majority of Hanwoo bovine by-products in terms of yield, physicochemical and nutritional compositions. Based on the results obtained, it is concluded that the yield, physicochemical and nutritional compositions significantly differed between the by-products. The parts of digestive tract including rumen, reticulum, omasum, abomasum and large intestine showed the highest pH values. Heart, liver, spleen, bladder, duodenum and reproductive organ are rich sources of protein comparable to the protein levels from muscle tissue. Furthermore, all beef by-products are rich sources of vitamins and trace elements with their levels/or amounts are considerably higher than those from muscle tissues. Additionally, most beef by-products showed desirable EAA/NE ratios, and the fatty acid profile in these beef by-products was similar to that in muscle tissues. This is the first study of comprehensive information about Hanwoo by-products therefore the data of the present study provide not only the useful information for consumers but also the important databases for further investigations.

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References

1. Alonso, V., Najes, L. M., Provincial, L., Guillén, E., Gil, M., Roncalés, P., and Beltrán, J. A. (2012) Influence of dietary fat on pork eating quality. *Meat Sci.* **92**, 366-373.
2. Anderson, B. A. (1988) Comparison and nutritional value of edible meat by-products. In: Edible Meat By-Products, Advance in Meat Research. Pearson, A. M. and Dutson, T. R (eds) Elsevier Applied Science Publisher Ltd., London, UK, pp. 15-45.
3. AOAC (2000) Official methods of analysis of the AOAC 986.15 Multi-element method. 17th ed, Arlington, Virginia, USA, pp. 1-8.
4. Aristoy, M. C. and Toldra, F. (2011) Essential amino acids. In: Handbook of Analysis of Edible Animal By-Products. Nollet, L. M. L. and Toldrá, F (eds) CRC Press, Boca Raton, FL, USA, pp. 123-135.
5. Aschner, J. L. and Aschner M. (2005) Nutritional aspects of manganese homeostasis. *Mol. Aspects Med.* **26**, 353-362.
6. Ba, H. V., Ryu, K. S., Nguyen, T. K. L., and Hwang, I. H. (2013) Influence of particular breed on meat quality parameters, sensory characteristics and volatile compounds. *Food Sci. Biotechnol.* **22**, 651-658.
7. Bendall, J. R. (1973) Postmortem changes in muscle. In: Structure and Function of Muscle. Bourne, G. H (ed) Academic Press, New York, pp. 243-309.
8. Benoist, B. (2001) Deficiency anemia: Reexamining the nature and magnitude of the public health problem. Introduction. *Nutrition* **131**, 564S.
9. Bray, G. A., Paeratakul, S., and Popkin, B. M. (2004) Dietary fat and obesity: a review of animal, clinical and epidemiological studies. *Physio. Behav.* **83,** 549-555.
10. Brugiapaglia, A., Lussiana, C., and Destefanis, G. (2014) Fatty acid profile and cholesterol content of beef at retail of Piemontese, Limousin and Friesian breeds. *Meat Sci.* **96**, 568-573.
11. Burlingame, B., Nishida, C., Uauy, R., and Weisell, R. (2009) Fats and fatty acids in human nutrition (Report of a joint FAO/WHO Export Consultation, November, 2008). *Ann. Nutr. Metab.* **55**, 1-380.
12. Costa, P., Roseiro, L. C., Bessa, R. J. B, Padilha, M., Partidario, A., Marques de Almeida, J., Calkins, C. R., and Santos, C. (2008) Muscle fiber and fatty acid profiles of Mertolenga-PDO meat. *Meat Sci.* **78,** 502-512.
13. Department of Health (1994) Nutritional aspects of cardiovascular disease (report on health and social subjects no 46). London UK: HMSO.
14. Devatkal, S., Mendiratta, S. K., Kondaiah, N., Sharma, M. C., and Anjaeyulu, A. S. R. (2004) Chysicochemical, functional and microbiological quality of buffalo liver. *Meat Sci.* **68**, 79-86.
15. Estevez, M., Ventanas, J., Cava, R., and Puolanne, E. (2005) Characterization of a traditional Finnish liver sausage and different types of Spanish liver pate: A comparative study. *Meat Sci.* **71**, 657-669.
16. Fatma, H. M. and Mahdey, E. A. (2010) Incidence of Bru-

cella species in slaughtered food animals and its edible offal at Beni-suef, Egypt. *Global Veterinaria* **5**, 248-254.
17. Faustman C. and Cassens, R. G. (1990). The Biochemical Basis for Discoloration in Fresh Meat: A Review. *J. Muscle Foods* **1**, 217-243.
18. Florek, M., Litwińczuk, Z., Skałecki, P., Kędzierska-Matysek, M., and Grodzicki, T. (2012) Chemical composition and inherent properties of offal from calves maintained under two production systems. *Meat Sci.* **90**, 402-409.
19. Folch, J., Lees, M., and Sloane-Stanley, G. H. (1957) A simple method for the isolation and purification of total lipid from animal tissue. *J. Biol. Chem.* **26**, 497-507.
20. Jo, C., Cho, S. H., Chang, J., and Nam, K. C. (2012) Keys to production and processing of Hanwoo beef: A perspective of tradition and science. *Animal Frontiers* **2**, 32-38.
21. Hallberg, L. and Hulthén, L. (2000) Prediction of dietary iron absorption: an algorithm for calculating absorption and bioavailability of dietary iron. *Am. J. Clin. Nutr.* **71**, 1147-1160.
22. Hermida, M., Gonzalez, M., Miranda, M., and Rodriguez-Otero, J. L. (2006) Mineral analysis in rabbit meat from Galicia (NW Spain). *Meat Sci.* **73,** 635-639.
23. Hoffman, L. C., Laubscher, L. L., and Leisegang, K. (2013) Nutritional value of cooked offal derived from free-range rams reared in South Africa. *Meat Sci.* **93**, 696-702.
24. Honikel, K. O. (2011) Composition and Calories. In: Handbook of Analysis of Edible Animal By-Products. Nollet, L. M. L. and Toldrá, F (eds) CRC Press, Boca Raton, FL, USA, pp. 105-121.
25. Kim, Y. B., Jeon, K. H., Lee, N. H., and Lee, H. J. (2008) An analysis of the nutritional quality of spreadable liver product. *Korean J. Food Sci. An.* **28**, 21-26.
26. Kim, Y. N. (2011) Vitamins. In: Handbook of Analysis of Edible Animal By-Products. Nollet, L. M. L. and Toldrá, F (eds) CRC Press, Boca Raton, FL, USA, pp. 161-182.
27. Kurt, S. and Zorba, O. (2007) Emulsion characteristics of beef and sheep offal. *J. Muscle Foods* **18**, 129-142.
28. Livestock and Products Annual (2013) Available from: http://www.agrochart.com/en/news/news/101113/korea-livestock-and-products-annual-sep-2013/. Accessed September, 2013.
29. Lebiedzinska, A. and Szefer, P. (2006) Vitamins B in grain and cereal-grain food, soy-products and seeds. *Food Chem.* **95**, 116-122.
30. Mandal, P. K., Rao, V. K., Kowale, B. N., and Pal, U. K. (1999) Utilization of slaughter house blood in human food. *J. Food Sci. Technol*. **36,** 91-105.
31. Mas, G., Llavall, M., Coll, D., Roca, R., Díaz, I., Oliver, M. A., Gispert, M., and Realini, C. E. (2011) Effect of an elevated monounsaturated fat diet on pork carcass and meat quality traits and tissue fatty acid composition from York-crossed barrows and gilts. *Meat Sci.* **89**, 419-425.
32. Moon, S. S., Yang, H. S., Park, G. B., and Joo, S. T. (2006) The relationship of physiological maturity and marbling judged according to Korean grading system to meat quality traits of Hanwoo beef females. *Meat Sci.* **74**, 516-521.
33. Morrison, W. R. and Smith, L. M. (1964) Preparation of fatty acid methyl esters and dimethylacetals from lipids with boron trifluoride-methanol. *J. Lipid Res.* **5**, 600-608.
34. Nollet, L. M. L. and Toldrá, F. (2011) Introduction of Offal meat: Definitions, regions, cultures, generalities. In: Handbook of Analysis of Edible Animal By-Products. Nollet, L. M. L. and Toldrá, F (eds) CRC Press, Boca Raton, FL, USA, pp 3-11.
35. Ockerman, H. W. and Basu, L. (2004) By-products. In: Encyclopedia of meat sciences. Jensen, W. K., Devine, C., and Dikeman, M (eds) Elsevier Academic Press, Amsterdam, London, pp. 104-112.
36. Okumura, T., Saito, K., Sowa, T., Sakuma, H., Ohhashi, F., Tameoka, N., Hirayama, M., Nakayama, S., Sato, S., Gogami, T., Akaida, M., Kobayashi, E., Konishi, K., Yamada, S., and Kawamura, T. (2012) Changes in beef sensory traits as somatic-cell-cloned Japanese black steers increased in age from 20 to 30 months. *Meat Sci.* **90**, 159-163.
37. Pearson, A. M. and Dutson, T. R. (1988) Edible meat by-products. In: Advances in meat Research. Elsevier Science Publishers Ltd, England. pp. 197.
38. Pereira, P. M. C. C. and Vicente, A. F. R. B. (2013) Meat nutritional composition and nutritive role in the human diet: Review. *Meat Sci.* **93,** 586-592.
39. Raes, K., Balcaen, A., Dirinck, P., De Winne, A., Claeys, E., Demeyer, D., and De Smet, S. (2003) Meat quality, fatty acid composition and flavor analysis in Belgian retail beef. *Meat Sci.* **65,** 1237-1246.
40. Ramos, A., Cabrera, M. C., and Saadoun, A. (2012). Bioaccessibility of Se, Cu, Zn, Mn and Fe, and heme iron content in unaged and aged meat of Hereford and Braford steers fed pasture. *Meat Sci*. **91**, 116-124.
41. Roach, P. J. (2002) Glycogen and its metabolism. *Curr. Mol. Med.* **2**, 101-120.
42. Santos, E. M., Fernández, C. G., Jaime, I., and Rovira, J. (2003) Physicochemical and sensory characterization of *Morcilla de Burgos*, a traditional Spanish blood sausage. *Meat Sci.* **65**, 893-898.
43. Sarries, M. V., Murray, B. E., Troy, D., and Beriain, M. J. (2006) Intramuscular and subcutaneous lipid fatty acid profile composition in male and female foals. *Meat Sci.* **72**, 475-485.
44. SAS Institute, Inc. (2007) SAS User's Guide. Release. 9.1.3. Statistical Analysis System Institute. Cary, NC, USA.
45. Savaran, E. G. and Pavlova, V. A. (1980) Amino acid composition of soft by-product of various poultry species. *Voprosy Pitaniya.* **4**, 71-74.
46. Selmane, D., Christophe, V., and Gholamreza, D. (2008) Extraction of proteins from slaughterhouse by-products: Influence of operating conditions on functional properties. *Meat Sci*. **79**, 640-647.
47. Simpson, R. J. and Mckie, A. T. (2009) Regulation of intestinal iron absorption: The mucosa takes control?. *Cell Metabolism*. **10**, 84-87.
48. Siri-Tarino, P. W., Sun, Q., Hu, F. B., and Krauss, R. M. (2010) Saturated fatty acids and risk of coronary heart disease: Modulation by replacement nutrients. *Curr. Atheroscler. Rep.* **12**, 384-390.

49. Spackman, D. H., Stein, W. H., and Moore, S. (1958) Automatic recording apparatus for use in chromatography of amino acids. *Anal. Chem.* **30**, 1190-1206.
50. Tapiero, H. and Tew, K. D. (2003) Trace elements in human physiology and pathology: zinc and metallothioneins. *Biomed. Pharmacother.* **57**, 399-411.
51. Toldra, F., Aristoy, M. C., Mora, L., and Reig, M. (2012) Innovations in value-addition of edible meat by-products. *Meat Sci.* **92**, 290-296.
52. USDA (2011) USDA National Nutrient Database for Standard Reference, Release 24. Nutrient Data Laboratory Home Page (http://www.ars.usda.gov/nutrientdata). Accessed March, 2012.
53. Wood, J. D., Richardson, R. I., Nute, G. R., Fisher, A. V., Campo, M. M., and Kasapidou, E. (2003) Effects of fatty acids on meat quality: A review. *Meat Sci.* **66**, 21-32.
54. Wu, G. (2010) Functional amino acids in growth, reproduction, and health. *Advances in Nutrition* **1**, 31-37.
55. Zotte, A. D. and Szendro, Z. (2011). The role of rabbit meat as functional food. *Meat Sci.* **88**, 319-331.

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