ARTICLE

Nutritional Characteristics and Active Components in Liver from *Wagyu×Qinchuan* Cattle

Ru-Ren Li, Qun-Li Yu*, Ling Han, and Hui Cao[1]

Department of Food Science and Engineering, Gansu Agricultural University, Lanzhou 730070, China
[1]Shaanxi Kingbull Company Limited, Baoji 722300, China

Abstract

We investigated nutritional characteristics and active components in the liver of *Wagyu×Qinchuan* cattle and *Qinchuan* cattle produced in Shaanxi (China). We observed significant differences ($p<0.05$) in the proximate composition of protein, fat, carbohydrate, total energy, and glycogen. *Wagyu×Qinchuan* cattle liver showed higher ($p<0.05$) sodium, iron, zinc, and selenium concentrations than *Qinchuan* cattle liver. The amino acid composition of *Wagyu×Qinchuan* cattle liver was richer ($p<0.05$) in 13 types of amino acids, with the exception of Asp (10.06%), Val (5.86%), and Met (1.72%). Total essential amino acids accounted for almost half the composition (39.69%) in *Wagyu×Qinchuan* cattle liver. *Wagyu×Qinchuan* cattle liver had lower ($p<0.05$) levels of monounsaturated fatty acids (18.2%), but higher ($p<0.05$) levels of polyunsaturated fatty acids (35.11%), compared with *Qinchuan* cattle liver (23.29% and 28.11%, respectively). The thrombogenic index was higher in *Qinchuan* cattle liver (0.86) than in *Wagyu×Qinchuan* cattle liver (0.70), and the glutathione (38.0 mg/100g) and L-carnitine (2.12 μM/g) content was higher ($p<0.05$) in *Wagyu×Qinchuan* cattle liver than in *Qinchuan* cattle liver (29.8 mg/100g and 1.41 μM/g, respectively). According to the results obtained, the liver of *Wagyu×Qinchuan* cattle, which is insufficiently used, should be increasingly utilized to improve its commercial value.

Key words: *Wagyu×Qinchuan* cattle, liver, nutritional characteristics, active components

Introduction

As an important edible meat by-product, liver constitutes approximately 1-2% of live weight in the bovine, and contains richer minerals and vitamins, compared with other muscular tissue. It is readily utilizable in many non-meat products (Lawrie and Ledward, 2006). China holds a 12% market share, and is one of the world's top five beef-producing countries. As one of the five best cattle breeds in China, *Qinchuan* cattle are classified as a national resource conservation breed. *Wagyu×Qinchuan* cattle (crossbred cattle) are a cross breed of *Wagyu* and *Qinchuan* cows from which increasing amounts of liver are produced in China. The abundant resource of liver makes its utilization scope and opportunities enormous. However, a considerable amount of liver is being used in the manufacture of animal feeds, from which return is undesirable. Therefore, it is essential and viable for the beef-processing industry to take measures to ensure its efficient utilization. An alternative is to take advantage of liver as a functional component in food. The Finnish liver sausage is popular with consumers, due to its quality; it possesses a beneficial fatty acid prole, high oxidative stability, and a balanced volatile prole (Estévez *et al.*, 2005). An investigation of the nutritional characteristics of crossbred cattle liver would be of great importance for those who regularly consume this type of meat.

The use of crossbred cattle liver as a meat product may produce greater returns, and it is essential to understand its active components in order to properly process inclusion in comminuted meat products. Only a fairly limited number of previous studies have focused on the nutritional characteristics and active components of meat by-products. Gorska *et al.* (1988) reported that the muscle layer of beef gullet meat tissue can be utilized as a substitute for processed beef, owing to a favorable balance of essential amino acids and a valuable source of mineral substances. Nuckles *et al.* (1990) found that there are four major protein fractions (low ionic strength solubility, high ionic strength solubility, insoluble protein, and collagen) in mechanically deboned chicken meat and meat by-prod-

*Corresponding author: Qun-Li Yu, Department of Food Science and Engineering, Gansu Agricultural University, Lanzhou 730070, China, Tel: 86-13893615810, Fax: 86-0931-7631201, E-mail: yuqunlihl@163.com

ucts (pork lung lobes, pork liver, beef lung lobes, beef spleen and beef heart). Rivera *et al*. (2000) discovered that the crude protein of pork by-products (lung lobes and kidneys) was higher than that of chicken viscera (head, feet, and viscera) and mechanically separated chicken. Pork lungs and chicken viscera contained the greatest amounts of insoluble proteins. Devatkal *et al*. (2004) indicated that buffalo liver contains higher amounts of water-soluble proteins (20-40%) than salt-soluble proteins (7-15%). The average microbial counts (Log CFU/g) for different organisms were also reported (aerobic plate counts, 6.10; psychrotrophs, 4.30; enterobacteriaceae counts, 4.97; staphylococcal counts, 2.50; and total coliforms, 2.82). Demarquoy *et al*. (2004) claimed that meat products were the best sources of L-carnitine. Dairy products and seafood are generally relatively low in L-carnitine, and vegetables are primarily very low in L-carnitine.

To the best of our knowledge, the nutritional characteristics and active components of *Wagyu×Qinchuan* cattle liver have scarcely been reported in the published literature. Therefore, our study objective was to evaluate the nutritional characteristics and active components of this type of liver, and to provide basic information to increase commercial utilization of liver.

Materials and Methods

Sample preparation

We obtained 15 *Wagyu×Qinchuan* cattle and 15 *Qinchuan* cattle from Kingbull Co., Ltd., China (the average age of the animals was 1 year). Liver samples from each breed were collected directly from the slaughter line, and washed with potable water to remove blood and other extraneous materials. Samples were separately packed in polyethylene bags and stored at -80°C until used (not more than 14 d later).

Estimation of proximate composition and mineral concentrations

Moisture, protein, fat, and ash content were determined in the liver samples (AOAC, 1995), and moisture was analyzed by drying the samples in a hot-air oven at 100±5°C until constant weight was obtained. Crude fat was determined using Soxhlet apparatus, ash was identified by incinerating the samples in a muffle furnace at 550-600°C until the weight of the residue became constant. Total nitrogen content was determined using the Kjeldahl procedure, and the conversion factor of 6.25 was used to calculate the protein content.

The mineral [sodium (Na), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), and copper (Cu)] concentrations of the samples were determined after a wet washing procedure using an atomic absorption spectrophotometer (SHIMADZU AA-7000 atomic absorption spectrophotometer, Japan), following the method described in AOAC (1995). In brief, a 5 g dry sample was weighed and placed in a digestion ask (50 mL), to which 20 mL HNO_3-$HClO_4$ (4:1) solution was added. The samples were left overnight (16 h), and then heated at 170-200°C until a clear solution was obtained and there were no fumes in the ask. The clear solution was transferred to a 50 mL volumetric ask, and diluted to volume with deionized water. Na, K, Ca, Mg, Fe, Zn, and Cu were measured according to the manufacturer's instructions.

Selenium (Se) concentration was determined according to the following procedure (Watkinson, 1966): a 0.3 g sample was weighed and placed in a digestion tube, to which 3.5 mL HNO_3-$HClO_4$ (2.5:1) mixture was added, and then left overnight (16 h). The tube was heated at 150°C until the volume was reduced to under 3.5 mL, then the temperature was increased to 190°C and held until the solution became clear. After cooling the tube, 0.2 mL HCl (1:1) was added. The tube was heated at 160°C for 20 min, and then the temperature was reduced to 130°C. Two blanks and three standards (Sodium selenite, Sigma Aldrich, Australia) were prepared in the same manner. After cooling, 2 mL 0.04 M EDTA in NH_4OH solution (1:1) with 0.001% bromocresol purple was added to the tube, and this was then reheated at 130°C until the solution became yellow. A total of 0.01 M HCl was added to make the solution up to 10 mL. An aliquot of 2 mL was then mixed with 0.32 mL of 0.05% (w/v) 2,3-diaminonaphthalene in 0.1 M HCl and vortexed to form uorescent derivative, after the derivative was extracted into 2 mL cyclohaxane and measured with a fluorescence spectrophotometer (SHIMADZU RF5301-PC Fluorescence Spectrophotometer, Japan) with excitation at 376 nm and emission at 520 nm.

Estimation of glycogen

To measure glycogen content, liver samples were scraped with 30% (w/v) KOH; the extract was then boiled for 15 min, and the resulting solution was spotted on chromatography paper 31 ET (Whatman, U.K.). Glycogen was precipitated by immersing the papers in ice-cold 66% (v/v) ethanol. After two washes in ethanol, the papers were air-dried and incubated with amyloglucosidase (Sigma Aldrich, Australia) as described by Chan and Exton (1976).

The resulting glucose was measured with a Gluco-quant kit (Roche Diagnostics GmbH, Germany). The concentration of glycogen was expressed as mg/g.

Amino acid analysis

The liver sample was hydrolyzed with 6 M HCl at 110 °C for 24 h. The hydrolysates were analyzed with an automated amino acid analyzer (HITACHI 835-50 Amino Acid Analyzer, Japan).

Fatty acid composition

Thee fatty acid composition of the samples was determined using gas chromatography, as described by López-López et al. (2009). Briey, boron triuoride/methanol was used for fatty acid methyl ester (FAME) preparation, and used a gas chromatograph (Model GC-2014, Japan), which was tted with a capillary column SP^{TM}-2330 (60 m × 0.25 mm × 0.2 μm i.d.) (Supelco, Inc., USA), with a ame ionization detector. The temperatures of the injector and the detector were set at 250°C and 260°C, respectively. The GC temperature program was initially maintained at 140 °C for 5 min, then raised to 240°C at a rate of 4°C/min and held for 20 min. We identified fatty acid concentrations by comparison with a known standard FAME mixture (Supelco, Alltech Associated, Inc., USA). The quantication of fatty acids has been reported by Delgado-Pando et al. (2010).

We computed the atherogenic index (AI) and thrombogenic index (TI) on the basis of the FAME results, according to Ulbricht and Southgate (1991).

AI = [12:0 + 4 × 14:0 + 16:0] / [PUFA (n-6 + n-3) + 18:1 + other monounsaturated fatty acids; MUFA];

TI = [14:0 + 16:0 + 18:0] / [0.5 × 18:1 + 0.5 × other MUFA + 0.5 × n-6 polyunsaturated fatty acids (PUFA) + 3 × n-3 PUFA + (n-3 PUFA) / (n-6 PUFA)].

Determination of glutathione content

Glutathione (GSH) concentration was determined following the method described by Sedlak and Lindsay (1968). A 0.3 g sample was homogenized in 3×1 mL 0.02 M EDTA, and 2.5 mL ice-cooled 10% TCA was immediately added. The sample was thoroughly vortexed the sample, and the solution was then centrifuged for 15 min at 4,000 g (4°C) to precipitate the protein. Approximately 300 μL of supernatant was transferred to a microcentrifuge tube, and centrifuged for 5 min at 1,800 g. The supernatant was used to determine GSH concentration by 5,5'-dithiobis (2-nitrobenzoic acid) as the reagent in a Cobas

Mira Diagnosica System (F. Hoffmann-La Roche, Switzerland). Fresh GSH standard solutions were prepared for each batch of the sample by dissolving reduced GSH standard (Sigma Aldrich, product No. G4251. Australia) in a solution that contained 0.04 M EDTA and 5% TCA.

Determination of L-carnitine content

Liver samples were prepared as described by Demarquoy et al. (2004). The samples were shredded, washed three times in an ice-cold homogenization buer, and then dried and weighted. The composition of this buer was Tris-HCl 100 mM, sucrose 25 mM, EDTA 1 mM, pH 7.5 (TSE buer), and the samples were homogenized in the buer with six strokes of a loose-tting Teon pestle at 200 rpm in an ice-cold Elvehjem potter. Generally, 100 mg of sample was dissolved in 0.7 mL of TSE buer. If L-carnitine concentration determination appeared out of range, other dilution ratios were used. The homogenate was centrifuged at 13,000 g for 30 min at 4°C, and the resulting supernatant was subsequently centrifuged at 100,000 g for 1 h at 4°C. The nal supernatant was immediately used for determination of L-carnitine amount present in food, which was estimated as described by Galland et al. (1998).

The sample, usually 0.05 mL in volume, was added to 100 μL of 1 M Tris base and 50 μL of 0.4 N KOH (pH of mixture approximately 13) and allowed to stand for 1 h at 37°C, in order to hydrolyze any acyl-carnitines. Thereafter, we 200 μL of 0.575 N HCl was added to allow the pH to return to 7.3, as well as 2 mM of sodium tetrathionate, and 25 nCi of [methyl-^{3}H]acetyl-CoA (25 μM). To initiate the reaction, one unit of L-carnitine acetyltransferase was added. After 15 min incubation at 37°C, 600 μL of Dowex resin (1×8, 200-400 mesh) was added to the mixture, which was then vigorously shaken. The resin is used to remove the unused acetyl-CoA. The tubes were incubated for 10 min and then centrifuged at 4,000 g for 2 min. We mixed the supernatant with scintillation liquid and counted in a Perkin Elmer Tri-Carb 2900TR scintillation counter (1 mL of supernatant for 3 mL of Perkin Elmer Ultima Gold scintillation liquid).

Statistical analysis

Experimental data are presented as mean±standard deviation (SD). Statistical comparisons were made using the statistical software package SPSS 17.0 (SPSS Inc., USA). The differences between the means of the groups were compared using analysis of variance at a significance level ($p<0.05$). All data presented are the mean values of three replicates.

Results and Discussion

Proximate composition

The average content of proximate composition in the two groups is presented in Table 1. Compared with *Qinchuan* cattle liver, crossbred cattle liver had a higher percentage of protein and fat, but a lower carbohydrate content ($p<0.05$). Mustafa (1988) and Park *et al.* (1991) reported relatively higher moisture (75.9% and 72.55%), and a lower fat level (3.26% and 2.21%) in sheep and goat livers, respectively. These contrasting results of proximate composition may be attributed to the dierences in species (Lawrie, 1981). The carbohydrate content of crossbred cattle liver (2.97%) was lower than the value (5.82%) that has been reported for beef liver (Shelef, 1975). Hedrick *et al* (1994) stated that carbohydrate constitutes up to 2-8% of fresh liver weight, as compared to 0.5-1.3% of fresh muscle weight. With regard to the ash content, we found no difference between crossbred cattle liver and *Qinchuan* cattle liver ($p<0.05$), which was similar to that of buffalo liver (Devatkal *et al.*, 2004). Lawrie (1981) reported that ash content was not affected by the variation in the moisture, fat, and protein content of meat. The total energy content of crossbred cattle liver was 136.05 kcal, and a similar value of 134 kcal energy has also been reported in beef liver (USDA, 1986). The caloric value of crossbred cattle liver supports its recommendation as part of a healthy diet for people with obesity and diabetes (Devatkal *et al.*, 2004). The recommended value of protein is 50 g (FDA, 2009). Therefore, 100 g liver per day would supply approximately 38% of the protein requirement for an adult.

Mineral concentrations

Mean concentrations of the dierent minerals in the liver samples are shown in Table 2. The Na content (70.05 mg/100g) was higher in crossbred cattle liver ($p<0.05$) than in *Qinchuan* cattle liver (65.23 mg/100g), but lower than the values reported in beef liver (73-81 mg/100g) and lamb liver (110 mg/100g). Similarly, the K content in crossbred cattle liver was lower than the values reported in beef. The Ca content of crossbred cattle liver was similar to values reported for livers of dierent species (Black *et al.*, 1985; Ono *et al.*, 1984), and the Mg content of crossbred cattle liver was similar to that of *Qinchuan* cattle liver. The Fe content of crossbred cattle liver (20.50 mg/100g) was higher ($p<0.05$) than that of *Qinchuan* cattle liver and sheep liver. The Fe content of crossbred cattle liver was five times more than that of beefsteak, with the latter

Table 1. Proximate composition of liver from *Qinchuan* and crossbred (*Wagyu* × *Quichuan*) cattle (n=15)

	Qinchuan cattle liver	Crossbred cattle liver
Moisture (%)	74.21±0.55[a]	72.08±0.60[a]
Protein (%)	17.47±0.36[a]	18.79±0.41[b]
Fat (%)	3.43±0.56[a]	5.02±0.06[b]
Carbohydrate (%)	3.74±0.19[a]	2.97±0.21[b]
Total ash (%)	1.15±0.12[a]	1.14±0.11[a]
Total energy (kcal)	103.02±0.88[a]	136.05±1.18[b]

[a,b]Mean values denoted with various letters in the same row are statistically signicantly different ($p<0.05$).

Table 2. Mineral concentrations of liver from *Qinchuan* and crossbred (*Wagyu* × *Quichuan*) cattle (mg/100g)

	Qinchuan cattle liver (n=15)	Crossbred cattle liver (n=15)
Na	65.23±2.13[a]	70.05±3.18[b]
K	265.56±11.22[a]	270.13±15.41[a]
Ca	5.34±0.17[a]	5.73±0.18[a]
Fe	12.63±1.02[a]	20.50±0.44[b]
Zn	1.71±0.46[a]	5.01±0.34[b]
Se	4.5±0.01[a]	9.90±0.05[b]
Mg	7.72±1.32[a]	7.99±1.64[a]
Cu	4.60±0.22[a]	5.30± 0.46[a]

[a,b]Mean values denoted with various letters in the same row are statistically signicantly different ($p<0.05$).

being 3.9 mg/100g (USDA, 1986). The Zn concentration in crossbred cattle liver was higher ($p<0.05$) than that of *Qinchuan* cattle liver, and almost equal to values reported in previous studies (USDA, 1986). The Cu content of crossbred cattle liver (5.3 mg/100g) was similar to that of *Qinchuan* cattle liver, but lower than that of sheep liver (Black *et al.*, 1985). The Se concentration was signicantly ($p<0.05$) higher in crossbred cattle liver, compared to *Qinchuan* cattle liver (Table 2). Recent studies have shown that there is an inverse relationship between Se status, cancer, and cardiovascular diseases (CVD) (Rayman, 2000). It has been suggested that supplementation with Se alters GSHPX activity, and enhances the immune system in cancer patients. Se induces the apoptosis that removes mutated or damages cells, and affects the production of testosterone (Gronberg, 2003). The role of Se in preventing CVD is due to its ability to prevent lipid peroxidation and avoid the formation of atherosclerotic plaques (Rayman, 2000).

Crossbred cattle liver is rich in Fe, Zn, and Se. Moreover, Fe contained in the liver is heme iron, which is several times more absorbable in the body than non heme iron presented in other foods. It is associated with an unidentied factor that increases absorbable Fe from all non heme sources (Hedrick *et al.*, 1994). Daily reference val-

ues for these minerals are 15 mg Zn, 18 mg Fe, and 70 μg Se per day for an adult (FDA, 2009). Therefore, a 100 g serving of crossbred cattle liver may provide 33% of required daily Zn, and more than 100% of required daily Fe and Se.

Glycogen

The average glycogen content of crossbred cattle liver was 6.32 mg/g, which is similar to the results reported for buffalo liver (7.07 mg/g) (Devatkal *et al.*, 2004). In contrast, Gill and Delacy (1982) reported 2.98 mg/g of glycogen in sheep liver. Shelef (1975) observed 5.3 mg/g glycogen in beef liver. The higher level of glycogen in liver is expected, since it is the body's primary glycogen storage organ (Lawrie, 1998).

Amino acid composition

To our knowledge, there are no reported data on the amino acid composition of crossbred cattle liver. Table 3 lists the amino acid concentrations of this type of liver in the present study. Compared with that of *Qinchuan* cattle liver, the amino acid composition of crossbred cattle liver was richer (*p*<0.05) in 13 types of amino acids, with the exception of Asp (10.06%), Val (5.86%), and Met (1.72%). Compared with fresh beef, Thr (4.43%), Ser (4.27%), Glu (15.85%), and Phe (5.61%) were higher in crossbred cattle liver, while the levels of other amino acids were similar to those observed in fresh beef (Lawrie and Ledward, 2006). Three of the most abundant amino acids in the

crossbred cattle liver were Glu at an average of 15.85%, followed by Asp at 10.06%, and Leu at 8.54%, which are similar to those noted in beef; 14.4%, 8.8%, and 8.4%, respectively (Lawrie and Ledward, 2006). The crossbred cattle liver was a good source of Lys (5.88%) and Met (1.72%), and total essential amino acids accounted for almost half of its composition (39.69%), which approximated that of the reference protein model proposed by the WHO/FAO.

Fatty acids composition

The fatty acid composition of crossbred cattle liver and *Qinchuan* cattle liver is presented in Table 4. We observed differences in the concentrations of 16:1, 18:0, 18:1 n-9, 18:1 n-11, and 20:3 n-3 acids (lower in the crossbred cattle liver), as well as in those of 18:2 n-6, 22:4 n-6, 22:5 n-3 and 22:6 n-3 acids (higher in the crossbred cattle liver). MUFA were lower in crossbred cattle liver (18.2%) than those in *Qinchuan* cattle liver (23.29%), and steer liver (19.4%), whereas PUFA were higher in crossbred cattle liver (35.11%) than in *Qinchuan* cattle liver (28.11%)

Table 3. Amino acid composition of liver from *Qinchuan* and crossbred (*Wagyu × Quichuan*) cattle (%)

Amino acid	*Qinchuan* cattle liver (n=15)	Crossbred cattle liver (n=15)
Asp	15.92±2.12[a]	10.06±1.55[b]
Thr	3.09±0.24[a]	4.43±0.38[b]
Ser	3.16±1.25[a]	4.27±1.02[b]
Glu	12.44±1.33[a]	15.85±1.50[b]
Gly	4.08±1.06[a]	5.07±1.75[b]
Ala	3.96±1.13[a]	5.43±1.14[b]
Val	8.54±0.13[a]	5.86±0.25[b]
Met	3.81±0.25[a]	1.72±0.34[b]
Ile	4.16±1.12[a]	5.16±1.74[b]
Leu	7.33±1.36[a]	8.54±1.65[b]
Tyr	1.32±1.10[a]	2.88±0.95[b]
Phe	4.10±1.26[a]	5.61±1.05[b]
Lys	5.07±1.04[a]	5.88±1.02[b]
His	1.26±0.12[a]	2.30±0.23[b]
Arg	4.22±1.24[a]	5.21±1.32[b]
Pro	3.02±1.22[a]	4.31±1.53[b]

[a,b]Mean values denoted with various letters in the same row are statistically signicantly different (*p*<0.05).

Table 4. Fatty acid composition of liver from *Qinchuan* and crossbred (*Wagyu × Quichuan*) cattle (%)

Fatty acid	*Qinchuan* cattle liver (n=15)	Crossbred cattle liver (n=15)
C14:0	1.12±0.45[a]	0.98±0.03[a]
C16:0	14.25±1.32[a]	14.31±0.40[a]
C16:1	5.23±1.70[a]	3.21±0.48[b]
C18:0	30.25±0.25[a]	25.03±0.15[b]
C18:1 n-9	16.56±0.55[a]	14.59±0.25[b]
C18:1 n-11	1.50±0.03[a]	0.40±0.15[b]
C18:2 n-6	10.05±0.35[a]	12.79±0.14[b]
C18:3 n-6	0.24±0.0.12[a]	0.27±0.05[a]
C18:3 n-3	0.75±0.15[a]	0.84±0.03[a]
C20:2 n-6	0.21±0.14[a]	0.22±0.06[a]
C20:3 n-3	2.04±0.20[a]	0.04±0.09[b]
C20:4 n-6	6.59±0.17[a]	7.11±0.24[a]
C20:5 n-3	0.60±0.05[a]	0.50±0.18[a]
C22:4 n-6	0.50±0.32[a]	2.62±0.00[b]
C22:5 n-3	6.23±0.25[a]	8.32±0.11[b]
C22:6 n-3	0.90±0.35[a]	2.4±0.45[b]
Σ SFA	45.62±2.55[a]	40.32±0.50[a]
Σ UFA	51.40±2.55[a]	53.31±0.50[b]
Σ MUFA	23.29±1.31[a]	18.20±0.92[b]
Σ PUFA	28.11±2.49[a]	35.11±0.81[b]
Σ n-3 PUFA	10.52±0.65[a]	12.10±0.52[b]
Σ n-6 PUFA	17.59±0.25[a]	23.01±0.15[b]
PUFA/SFA	0.62±0.05[a]	0.87±0.05[b]
n-6/n-3	1.67±0.08[a]	1.90±0.06[a]
Atherogenic index (AI)	0.36±0.03[a]	0.34±0.02[a]
Thrombogenicindex (TI)	0.86±0.03[a]	0.70±0.01[b]

[a,b]Mean values denoted with various letters in the same row are statistically signicantly different (*p*<0.05).

and steer liver (29.8%) (Enser *et al*., 1998).

The PUFA/saturated fatty acids (SFA) ratio is one of the main parameters used to estimate the nutritional quality of the lipid fraction of foods. The recommended healthy ratio of PUFA/SFA was above 0.4, and the ratio of n-6 to n-3 fatty acids was between 1 and 4 (DHSS, 1994). The n-6:n-3 ratio of crossbred cattle liver (1.90) was higher than steer liver (0.72) (Enser *et al*., 1998). It has been linked to a reduced risk of various pathologies, including diabetes, cancer, and CVD. Meanwhile, the crossbred cattle liver maintained a higher P:S ratio (0.87) than the *Qinchuan* cattle liver (0.62) and steer liver (0.76) (Enser *et al*., 1998). A higher ratio of P:S has been related to a reduction of total cholesterol in blood (McAfee *et al*., 2010). In addition, human health is affected by SFA, MUFA, and PUFA other than n-3 PUFA. Lipid quality indicators depend on the AI and TI, which indicate the global dietetic quality of lipids and their potential effect on the development of coronary disease (Ulbricht and Southgate, 1991). In the present study, the value of TI in crossbred cattle liver (0.70) was lower than that of *Qinchuan* cattle liver (0.86) and steer liver (1.41) (Enser *et al*., 1998).

GSH concentration

The average GSH concentration of crossbred cattle liver (38.0 mg/100g) was higher than that of *Qinchuan* cattle liver (29.8 mg/100g) ($p<0.05$). GSH is a primary antioxidant in the endogenous antioxidant system, as it is more concentrated than other endogenous antioxidant compounds, and its greater redox potential can reduce the oxidants that cause lipid peroxidation. This is a probable explanation of our nding that the high GSH concentration in the liver reduced peroxidation of PUFA, and thus resulted in a relatively higher concentration of PUFA in crossbred cattle liver. Moreover, it has been well established that dietary GSH enhances metabolic clearance and decreases net absorption of dietary lipid peroxidation (Buettner, 1993). GSH is present in most plant and animal tissues from which the human diet is derived, and Flagg *et al*. (1994) reported that consumption of food high in GSH can reduce signicantly the risk of oral and pharyngeal cancer.

L-carnitine concentration

The L-carnitine concentrations were signicantly ($p<0.05$) higher in crossbred cattle liver (2.12 μM/g) than in *Qinchuan* cattle liver (1.41 μM/g) and camel liver (1.40 μM/g) (Alhomida *et al*., 1995). Many studies have indicated that L-carnitine plays a major role in fatty acid metabo-

lism by facilitating the entry of fatty acids into the mitochondria, and also their subsequent oxidation (Galland *et al*., 2001). At least 80% of L-carnitine can be provided by the food supply (Rigault *et al*., 2008). The recommended L-carnitine intake ranges from 140 to 840 μM per day for a 70 kg human being, with an average daily recommendation of 490 μM (Galland *et al*., 2001). Therefore, an average of 200 g of liver per day is enough to meet this recommendation, which means that crossbred cattle liver plays an essential role in the provision of L-carnitine.

Conclusion

Our results indicate that crossbred (*Wagyu×Quichuan*) cattle liver is an economically viable and rich source of essential nutrients, such as proteins, Fe, Zn, and Se. Moreover, the essential amino acids of crossbred cattle liver contain 39.69% of total amino acids, which are beneficial for the human health. In particular, we observed that Leu (8.54%) was the most abundant essential amino acid in crossbred cattle liver, and was found at a similar level to that which is found in fresh beef (8.4%). In addition, crossbred cattle liver fat contains 35.11% of PUFA. It is also has a lower TI (0.70), which indicates the global dietetic quality of lipids. Furthermore, the crossbred cattle liver was a valuable source of GSH (38.0 mg/100g) and L-carnitine (2.12 μM/g). Further investigations may be necessary to survey the nutritional characteristics of *Wagyu* cattle liver, and crossbred cattle liver from different slaughter age (18, 24 mon). This economically viable and crossbred cattle liver could become increasingly commercially utilized for human consumption, as a result of the possibilities it offers with regard to processing and incorporation in many food formulations.

Acknowledgements

References

1. Alhomida, A. S., Duhaiman, A. S., Al-Jafari, A. A., and Junaid, M. A. (1995) Determination of L-carnitine, acylcarnitine and total carnitine levels in plasma and tissues of camel (*Ca-*

melus dromedarius). *Comp. Biochem. Phys. B.* **111**, 441-445.

2. AOAC, 1995. *Ocial Methods of Analysis*. 16ᵗʰ Ed., Washington, DC, USA.

3. Black, J. R., Ammerman, C. B., and Henry, P. R. (1985) Eect of high dietary manganese as manganese oxide or manganese carbonate in sheep. *J. Food Sci.* **60**, 861-864.

4. Buettner, G. R. (1993) The pecking order of free radicals and antioxidants: Lipid peroxidation, alpha-tocopherol, and ascorbate. *Arch. Biochem. Biophys.* **300**, 535-543.

5. Chan, T. M. and Exton, J. H. (1976) A rapid method for the determination of glycogen content and radioactivity in small quantities of tissue or isolated hepatocytes. *Anal. Biochem.* **71**, 96-105.

6. Delgado-Pando, G., Cofrades, S., Ruiz-Capillas, C., and Jiménez-Colmenero, F. (2010) Healthier lipid combination as functional ingredient in sensory and technological properties of low-fat frankfurters. *Eur. J. Lipid Sci. Tech.* **112**, 859-870.

7. Demarquoy, J., Georges, B., Rigault, C., Royer, M., Clairet, A., and Soty, M. et al. (2004) Radioisotopic determination of L-carnitine content in foods commonly eaten in western countries. *Food Chem.* **86**, 137-142.

8. Devatkal, S., Mendiratta, S. K., Kondaiah, N., Sharma, M. C., and Anjaneyulu, A. S. R. (2004) Physicochemical, functional and microbiological quality of buffalo liver. *Meat Sci.* **68**, 79-86.

9. DHSS. (1994) Report on Health and Social Subjects No. 46. *Nutritional Aspects of Cardiovascular Disease*. London.

10. Enser, M., Hallett, K. G., Hewett, B., Fursey, G. A. J., Wood, J. D., and Harrington, G. (1998) The polyunsaturated fatty acid composition of beef and lamb. *Meat sci.* **49**, 321-327.

11. Estévez, M., Ventanas, J., Cava, R., and Puolanne, E. (2005) Characterisation of a traditional Finnish liver sausage and dierent types of Spanish liver pâtés: A comparative study. *Meat Sci.* **71**, 657-669.

12. Flagg, E. W., Coates, R. J., Jones, D. P., Byers, T. E., Greenberg, R. S., and Gridley, G. et al. (1994) Dietary glutathione intake and the risk of oral and pharyngeal cancer. *Am. J. Epidemiol.* **139**, 453-465.

13. Galland, S., Le Borgne, F., Georges, B., and Demarquoy, J. (2000) Carnitine, cellular and molecular aspects. *Recent Res. Dev. Lipids* **5**, 1-14.

14. Galland, S., Le Borgne, F., Guyonnet, D., Clouet, P., and Demarquoy, J. (1998) Purication and characterization of the rat liver gamma-butyrobetaine hydroxylase. *Mol. Cell. Biochem.* **178**, 163-168.

15. Gill, C. O. and Delacy, K. M. (1982) Microbial spoilage of whole sheep livers. *Appl. Environ. Microbiol.* **43**, 1262-1266.

16. Gorska, I., Szmanko, T., and Krasnowska, G. (1988) Preliminary physicochemical and histological characteristics of beef gullet tissue. *Food Chem.* **27**, 131.

17. Gronberg, H. (2003) Prostate cancer epidemiology. *Lancet* **361**, 859-864.

18. Hedrick, H. B., Aberle, E. D., Forrest, J. C., Judge, M. D., and Merkel, R. A. (1994) Nutritive value of meat. In: *Principles of meat science*. 3ʳᵈ Ed., pp. 289-298. Kendall Hunt Publishing Co. Dubuque, USA.

19. Lawrie, R. A. (1981) Nutrient variability due to species and product. In: *Meat in nutrition and health*. (eds. K. R. Franklin and P. N. Davis), National Livestock and Meat Board, Chicago, USA.

20. Lawrie, R. A. (1998) *Lawrie's meat science*. 6ᵗʰ Ed., Woodhead Publishing Ltd, Cambridge, England.

21. Lawrie, R. A. and Ledward, D. A. (2006) *Lawrie's meat science*. 7ᵗʰ Ed., Woodhead Publishing Ltd, Cambridge, England.

22. López-López, I., Cofrades, S., Ruiz-Capillas, C., and Jiménez-Colmenero, F. (2009) Design and nutritional properties of potential functional frankfurters based on lipid formulation, added seaweed and low salt content. *Meat Sci.* **83**, 255-262.

23. Mcafee, A. J., Mcsorley, E. M., Cuskelly, G. J., Moss, B. W., Wallace, J. M. W., Bonham, M. P., and Fearon, A. M. (2010) Red meat consumption: An overview of the risks and benets. *Meat Sci.* **84**, 1-13.

24. Mustafa, F. A. (1988) Moisture, fat and cholesterol content of some raw, barbecued and cooked organ meats of beef and mutton. *J. Food Sci.* **53**, 270-271.

25. Nuckles, R. O., Smith, D. M., and Merkel, R. A. (1990) Meat by-product protein composition and functional properties in meat model systems. *J. Food Sci.* **53**, 640-644.

26. Ono, K., Berry, B. W., Johnson, H. K., Russek, E., Parker, C. F., Cahill, V. R., and Althouse, P. G. (1984) Nutrient composition of lamb of two age groups. *J. Food Sci.* **49**, 1233-1236.

27. Park, Y. W., Kouassi, M. A., and Chin, K. B. (1991) Moisture, total fat and cholesterol in goat organ and muscle meat. *J. Food Sci.* **56**, 1191-1193.

28. Rayman, M. P. (2000) The importance of selenium to human health. *Lancet* **356**, 233-241.

29. Rigault, C., Mazué, F., Bernard, A., Demarquoy, J., and Le Borgne, F. (2008) Changes in L-carnitine content of sh and meat during domestic cooking. *Meat Sci.* **78**, 331-335.

30. Rivera, J. A., Sebranek, J. G., Rust, R. E., and Tabatabai, B. L. (2000) Composition and protein fractions of dierent meat by-products used for pet food compared with mechanically separated chicken (MSC). *Meat Sci.* **55**, 53-59.

31. Sedlak, F. and Lindsay, R. H. (1968) Estimation of total, protein-bound and nonprotein sulfhydryl groups in tissue with Ellman's reagent. *Anal. Biochem.* **25**, 192-205.

32. Shelef, L. A. (1975) Microbial spoilage of fresh refrigerated beef liver. *J. Appl. Bacteriol.* **39**, 273-280.

33. Ulbricht, T. L. V. and Southgate, D. A. T. (1991) Coronary heart-disease-7 dietary factors. *Lancet* **338**, 985-992.

34. USDA. (1986) Composition of foods: Beef products raw, processed, prepared. *Agriculture Handbook* No. 8-13. Washington, DC, USA.

35. Watkinson, J. H. (1966) Fluorometric determination of selenium in biological material with 2,3-diaminonaphthalene. *Anal. Chem.* **38**, 92-97.