Comparison of Amino Acid and Fatty Acid Nutritional Values and Textural Characteristics between Duck Foie Gras and Goose Foie Gras (Postprint)

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Abstract

This study analyzed and nutritionally evaluated the basic nutritional components, amino acids, and fatty acids of duck and goose fatty livers to compare differences in their amino acid and fatty acid nutritional values and textural characteristics. Goose fatty liver with a 28-day force-feeding period and duck fatty liver with a 14-day force-feeding period were selected for determination and analysis using instruments including an amino acid analyzer and gas chromatograph to compare their nutritional value differences. The results showed: 1) Moisture and crude fat contents in duck fatty liver were extremely significantly lower than in goose fatty liver ($P<0.01$), while crude ash and crude protein contents were extremely significantly higher ($P<0.01$). 2) Both liver types contained the same amino acid types, with tryptophan undetected in either; contents of remaining amino acids (except cysteine and proline) showed significant or extremely significant differences ($P<0.05$ or $P<0.01$). The Essential Amino Acid Index (EAAI) was 64.34 for duck fatty liver and 60.25 for goose fatty liver; the Score of Ratio Coefficient (SRC) was 73.34 for duck fatty liver and 47.11 for goose fatty liver; flavor amino acid proportion was higher in goose fatty liver, while medicinal amino acid content was higher in duck fatty liver. 3) Goose fatty liver contained 61.70% unsaturated fatty acids and 39.31% saturated fatty acids; duck fatty liver contained 59.11% unsaturated fatty acids and 41.25% saturated fatty acids. The ratio of saturated, monounsaturated, and polyunsaturated fatty acids in goose fatty liver was 5.53:7.69:1.00, indicating superior fatty acid nutritional value compared to duck fatty liver. 4) Chromium, copper, iron, and phosphorus contents in duck fatty liver were extremely significantly higher than in goose fatty liver ($P<0.01$), while calcium content in goose fatty liver was extremely significantly higher than in duck fatty liver ($P<0.01$). 5)

Hardness of duck fatty liver was extremely significantly higher than goose fatty liver ($P<0.01$), while adhesiveness was extremely significantly lower ($P<0.01$). These results demonstrate that duck fatty liver has higher amino acid nutritional value, while goose fatty liver has higher fatty acid nutritional value; goose fatty liver exhibits better tenderness, while duck fatty liver shows higher hardness.

Full Text

Comparison on Amino Acids and Fatty Acids Nutritive Value and Texture Characteristics in Duck Fatty Liver and Goose Fatty Liver

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Abstract

This study was conducted to compare the difference of amino acids and fatty acids nutritive value and texture characteristics in duck fatty liver and goose fatty liver through analyzing and evaluating the basic nutrient composition, amino acids and fatty acids in duck fatty liver and goose fatty liver. The fatty livers were selected from the goose and duck overfeeding period lasted for 28 and 14 days, respectively. The difference of nutritive values of duck fatty liver and goose fatty liver were tested by using of amino acid analyzer, gas chromatograph and so on. The results showed as follows: 1) the contents of moisture and crude lipid in duck fatty liver were significantly lower than those in goose fatty liver ($P<0.01$), and the contents of crude ash and crude protein were significantly higher than those in goose fatty liver ($P<0.01$). 2) The amino acid types of duck fat liver and goose fatty liver were the same, tryptophan was not detected, the other amino acids (except cysteine and proline) contents had significant differences between duck fat liver and goose fatty liver （$P<0.05$ or $P<0.01$）. The essential amino acid index (EAAI) of duck fat liver and goose fatty liver were 64.34 and 60.25 respectively. The amino acid ratio coefficient score (SRC) of duck fat liver and goose fatty liver protein were 73.34 and 47.11 respectively. The ratio of the taste amino acids in goose fatty liver was higher than that in duck fat liver, the content of therapeutic amino acids in duck fat liver was higher than that in goose fat liver. 3) The contents of unsaturated fatty acids and saturated fatty acids were 61.70% and 39.31% in goose fat liver, the contents of unsaturated fatty acids and saturated fatty acids were 59.11% and 41.25%

in duck fatty liver. The ratio of saturated fatty acid, monounsaturated fatty acid and polyunsaturated fatty acid in goose fatty liver was 5.53:7.69:1.00, the nutritive value of fatty acids in goose fatty liver was better than duck fatty liver. 4) The contents of chromium, copper, iron and phosphorus in duck fatty liver were significantly higher than those in goose fatty liver ($P<0.01$), the content of calcium in goose fatty liver was significantly higher than that in duck fatty liver ($P<0.01$). 5) The hardness of duck fatty liver was significantly higher than that of goose fatty liver ($P<0.01$), the adhesiveness of duck fatty liver was significantly lower than that of goose fatty liver ($P<0.01$). In conclusion, the nutritive value of amino acids in duck fat liver is higher than goose fatty liver, the nutritive value of fatty acids in goose fatty liver is higher than duck fat liver. Goose fatty liver has better tenderness, duck fat liver has high hardness.

Keywords: duck fat liver; goose fatty liver; amino acids; fatty acids; texture characteristics; evaluate

Introduction

Fatty liver, particularly from ducks and geese, is highly valued for its nutritional and therapeutic properties. It can reduce cholesterol deposition on vascular walls, alleviate and delay vascular sclerosis, and offers high nutritional and dietary therapy value [2-3]. In Europe, especially France, it is classified as a "national-level food" and hailed as the "king of world green foods." Previous research has focused on various aspects of fatty liver production and quality. Zeng et al. [4] investigated changes in conventional nutrients, fatty acid composition, and lipid peroxidation in three different qualities of duck fatty liver after cooking, finding that changes in fatty acid content during cooking were influenced by the composition and total fat content of fresh fatty liver. Peng et al. [5] conducted force-feeding experiments on Landes geese, reporting high contents of various essential amino acids, with glutamic acid (Glu) at 4.47% and unsaturated fatty acids at 73.94%, indicating high nutritional value. Lu et al. [6] studied the effects of different oils and vitamin E on fatty acid content in Cherry Valley duck fatty liver, showing that adding camellia oil, sesame oil, or soybean oil at 2% levels increased unsaturated fatty acid content, as did vitamin E at 90 IU/kg. Fan [7] found that goose oil, corn oil, and sheep oil could improve goose liver weight, while soybean oil was least effective; different fats had minimal impact on total unsaturated fatty acids but significantly altered fatty acid composition. To date, research on duck and goose fatty liver has concentrated on feeding methods and liver formation mechanisms, while studies on their nutritional value and texture characteristics remain limited. Therefore, this paper employs biochemical analysis and texture analyzer measurements to evaluate the conventional nutrients, amino acids, fatty acids, and texture characteristics of both duck and goose fatty liver, aiming to scientifically assess their nutritional value and texture properties and provide theoretical basis for determining fatty liver functionality and guiding rational consumption.

1.1 Materials Selection

Based on actual production practices in China, fatty liver samples were purchased from three goose fatty liver producers with a feeding period of 28 days, and two duck fatty liver producers with a feeding period of 14 days.

1.2 Experimental Design

Thirty goose fatty livers and thirty duck fatty livers were selected. Fresh samples were immediately analyzed for routine nutritional components (moisture, crude protein, crude fat, and crude ash). Another portion was homogenized into fatty liver paste under ice bath conditions, vacuum freeze-dried, and stored at -20°C for determination of amino acids, fatty acids, and texture indicators. Statistical analysis was performed to identify compositional differences.

1.3 Main Instruments and Reagents

The main instruments included a Hitachi 8900 high-speed amino acid analyzer (Japan), ICP-OES-Optima 8x00 spectrometer (USA), Kjeldahl nitrogen analyzer (FOSS-2100, Sweden), and 6890N gas chromatograph (Agilent, USA). Reagents included analytical grade sodium chloride (NaCl), hydrochloric acid, sulfuric acid, perchloric acid, and isooctane from Tianjin Kemio Chemical Reagent Co., Ltd.

1.4 Methods

1.4.1 Determination of Routine Nutritional Components Moisture content was determined according to GB/T 5009.3—2016; crude protein content according to GB/T 5009.5—2016; crude fat content according to GB/T 5009.6—2016; crude ash content according to GB/T 5009.4—2016; amino acid content according to GB/T 5009.124—2016; and fatty acid content according to GB/T 5009.168—2016 using the external standard-ester exchange method.

1.4.2 Determination of Taste Amino Acid Content The content of umami amino acids was calculated as the sum of glutamic acid and aspartic acid (Asp); sweet amino acids as the sum of alanine (Ala), glycine (Gly), serine (Ser), and proline (Pro); and aromatic amino acids as the sum of tyrosine (Tyr) and phenylalanine (Phe). The proportions of these taste amino acids to total amino acids were also calculated [8].

1.4.3 Evaluation Methods for Nutritional Value Amino acid score (AAS) was calculated according to the method proposed by WHO and FAO [9]; chemical score (CS) was calculated using the method recommended by Seligson et al. [10]; and essential amino acid index (EAAI) was calculated based on the method proposed by Oser [11-12]:

$$AAS = AAT / AAC$$
$$CS = AAT / AACA$$

Where: AAT is the amino acid content in the sample (mg/g); AAC is the content of the same amino acid in the FAO/WHO scoring standard pattern (mg/g); AACA is the content of the same amino acid in whole egg protein (mg/g); n is the number of essential amino acids compared; a, b, ···i are the essential amino acid contents in the sample protein (mg/g); and ae, be, ···ie are the essential amino acid contents in whole egg protein (mg/g).

1.4.4 Ratio Coefficient of Amino Acid (RC) Method The ratio coefficient of amino acid (RC) and score of RC (SRC) were calculated according to the method proposed by Zhu and Wu [13].

1.4.5 Determination of Trace Element Content Trace elements including iron (Fe), copper (Cu), calcium (Ca), phosphorus (P), selenium (Se), zinc (Zn), chromium (Cr), manganese (Mn), magnesium (Mg), and lead (Pb) were determined in liver water extracts using inductively coupled plasma optical emission spectrometry (GFAAS).

1.4.6 Determination of Texture Characteristics Texture profile analysis (TPA) was performed using a TA-XT texture analyzer. Fresh fatty liver samples were cut into 2.0 cm × 2.0 cm × 1.5 cm pieces. A P6 cylindrical probe was used with pre-test speed of 2 mm/s, post-test speed of 3 mm/s, test speed of 1 mm/s, interval time of 5 s, compression ratio of 50%, and trigger type of auto~5 g. TPA measurements were performed in triplicate.

1.5 Data Processing

Data were expressed as mean ± standard deviation (mean±SD) and processed using SPSS 17.0 software. Differences between groups were determined by t-test (two-tailed) analysis.

2 Results

2.1 Routine Nutritional Composition of Duck and Goose Fatty Liver

The routine nutritional composition of duck and goose fatty liver is shown in Table 1 . The moisture and crude fat contents in duck fatty liver were significantly lower than those in goose fatty liver ($P<0.01$), while the crude ash and crude protein contents were significantly higher ($P<0.01$).

2.2 Amino Acid Analysis

2.2.1 Amino Acid Composition and Content The amino acid composition and content in duck and goose fatty liver are presented in Table 2 . Seventeen amino acids were detected in both types (tryptophan was not detected).

The total amino acid content in duck fatty liver was 4.94%, higher than 4.03% in goose fatty liver. Both contained histidine essential for child growth, with leucine being the most abundant essential amino acid at 0.510% and 0.413%, respectively.

The essential amino acid/total amino acid (EAA/TAA) ratios were 41.90% for duck and 40.77% for goose fatty liver, and the essential amino acid/non-essential amino acid (EAA/NEAA) ratios were 72.13% and 68.85%, respectively. Both ratios exceeded the FAO/WHO recommended ideal protein pattern (EAA/TAA 40%, EAA/NEAA 60%), indicating that both duck and goose fatty liver are rich in amino acids with complete types and balanced proportions, constituting high-quality protein for human nutrition. Glutamic acid was the most abundant amino acid in both, contributing to the delicious taste.

2.2.2 Content and Ratio of Taste Amino Acids The content and ratio of taste amino acids are shown in Table 3 . The descending order of taste amino acid content was: aromatic > umami > sweet. Although duck fatty liver contained higher absolute amounts of each taste amino acid category, goose fatty liver showed higher proportions of umami and sweet amino acids, suggesting a more delicious flavor. The three types of taste amino acids accounted for 51.88% and 53.74% of total amino acids in duck and goose fatty liver, respectively, representing relatively high overall contents.

2.2.3 Essential Amino Acid Content and AAS The essential amino acid content and AAS are presented in Table 4 . Total essential amino acid contents were 310 mg/g and 301 mg/g in duck and goose fatty liver, respectively, below the FAO/WHO standard of 360 mg/g and egg protein' s 512 mg/g. The AAS for phenylalanine + tyrosine exceeded 1 in both, while lysine and leucine AAS values approached 1, indicating that essential amino acids in fatty liver closely match WHO/FAO recommended standards with high nutritional value. Based on AAS, the first limiting amino acid in duck fatty liver was valine, and the second was threonine; in goose fatty liver, the first limiting was methionine + cysteine, and the second was valine. Based on CS, the first limiting amino acid in both was methionine + cysteine, and the second was valine. The EAAI values were 64.34 for duck and 60.25 for goose fatty liver, indicating better essential amino acid balance in duck fatty liver protein.

2.2.4 SRC of Proteins The SRC of proteins in duck and goose fatty liver is shown in Table 5 . In duck fatty liver, the RC values for phenylalanine + tyrosine, valine, and threonine were dispersed, with phenylalanine + tyrosine being excessive and valine and threonine being limiting. In goose fatty liver, RC values for phenylalanine + tyrosine, lysine, leucine, methionine + cysteine, and valine were dispersed, with phenylalanine + tyrosine, lysine, and leucine being excessive and methionine + cysteine and valine being limiting. Other amino acids in both had RC values around 1.00, approaching amino acid balance mode. Methionine + cysteine showed the most dispersed RC value in goose fatty liver, representing the greatest negative contribution to physiological balance and serving as the first limiting amino acid, with valine as the second limiting amino acid. In duck fatty liver, valine was the first limiting amino acid and threonine the second, consistent with AAS results. The SRC values were 73.34 for duck and 47.11 for goose fatty liver, indicating higher protein nutritional value in duck fatty liver.

2.3 Therapeutic Amino Acid Composition

The therapeutic amino acid composition is illustrated in Figure 1 [Figure 1: see original paper]. Glutamic acid was the most abundant therapeutic amino acid in both duck and goose fatty liver, followed by leucine, aspartic acid, and lysine, with methionine being the least abundant. All therapeutic amino acids were present at higher levels in duck than in goose fatty liver, indicating greater therapeutic amino acid value in duck fatty liver.

2.4 Fatty Acid Composition and Content

The fatty acid composition and content are presented in Table 6 . Eight fatty acids were detected, including 4 saturated, 1 monounsaturated, and 3 polyunsaturated fatty acids. Duck fatty liver contained lower unsaturated fatty acid content (59.11%) than goose fatty liver (61.70%), and lower polyunsaturated fatty acid content (3.59%) than goose fatty liver (7.10%). Palmitic acid (C16:0), stearic acid (C18:0), and oleic acid (C18:1) were the most abundant free fatty acids. Palmitic acid content was significantly lower in duck than in goose fatty liver ($P<0.01$), while stearic acid content was significantly higher ($P<0.01$). Other fatty acids showed no significant differences ($P>0.05$).

The ratios of saturated:monounsaturated:polyunsaturated fatty acids were 11.49:15.47:1.00 in duck fatty liver and 5.53:7.69:1.00 in goose fatty liver, indicating that goose fatty liver composition more closely approaches the recommended human dietary intake ratio of 1:1:1.

2.5 Trace Element Content

Trace element contents are shown in Table 7 . Chromium, copper, iron, and phosphorus contents were significantly higher in duck than in goose fatty liver ($P<0.01$), while calcium content was significantly higher in goose than in duck fatty liver ($P<0.01$). Cadmium, magnesium, and zinc contents showed no significant differences ($P>0.05$), though zinc was relatively abundant.

2.6 Texture Characteristics

Texture characteristics are presented in Table 8 . Duck and goose fatty liver exhibited different textural properties. Duck fatty liver hardness was significantly higher than goose fatty liver ($P<0.01$), while adhesiveness was significantly lower ($P<0.01$). No significant differences were observed in cohesiveness, springiness, gumminess, chewiness, or resilience ($P>0.05$). Specifically, duck fatty liver hardness was 28.12% higher than goose fatty liver. Cohesiveness, gumminess, and chewiness were also higher in duck fatty liver by 1.2%, 30.7%, and 26.5%, respectively, while adhesiveness, springiness, and resilience were lower. These results indicate that goose fatty liver possesses characteristics of lower hardness, higher adhesiveness, and better springiness, suggesting superior tenderness and elasticity compared to duck fatty liver.

3 Discussion

3.1 Analysis of Amino Acid Nutritional Value

The nutritional value of food protein depends primarily on the types, quantities, and composition of essential amino acids. In this study, duck and goose fatty liver were rich in lysine (0.420% and 0.323%) and leucine (0.510% and 0.413%) among essential amino acids, with glutamic acid (0.577% and 0.507%) being the most abundant non-essential amino acid. Lysine, the first limiting amino acid in cereal foods and the first essential amino acid for humans, plays crucial roles in nutrient absorption, utilization, and growth promotion. Glutamic acid participates in erythropoiesis and excitatory transmission, benefiting brain function improvement and maintenance, making fatty liver consumption potentially therapeutic for neurasthenia and memory impairment.

The daily requirements for essential and non-essential amino acids for an adult male are 0.18 and 0.48 g/kg, respectively, corresponding to EAA/NEAA of 37.5% and EAA/TAA of 27.3% [9]. The EAA/NEAA and EAA/TAA ratios in both duck and goose fatty liver exceeded FAO/WHO recommendations [14], fully meeting adult male daily requirements. Therefore, the proteins in both types of fatty liver exhibit high nutritional value.

AAS and CS reflect protein composition and utilization from different perspectives, while EAAI is a common indicator for evaluating food nutritional value, using egg protein essential amino acids as the reference standard. EAAI values closer to 100 indicate higher nutritional value [15]. Modern research suggests that both amino acid deficiency and excess limit protein nutritional value, leading to the amino acid balance theory. The RC and SRC values calculated based on this theory are closer to biological valence (BV) than AAS calculated using the FAO model and are widely used for protein nutritional evaluation. SRC values closer to 100 indicate superior protein nutritional value [16]. This study demonstrates that duck fatty liver protein exhibits better essential amino acid balance than goose fatty liver based on AAS, CS, and SRC evaluations.

Among the 20+ amino acids in nature, nine including glutamic acid, aspartic acid, arginine, glycine, phenylalanine, tyrosine, methionine, leucine, and lysine are generally low in plants, cannot be synthesized by humans, yet are essential for maintaining nitrogen balance, thus termed therapeutic amino acids. In this study, therapeutic amino acids accounted for approximately 60% of total amino acids in both fatty livers, ranking below Codonopsis (70%) [17] but above loquat

(56%) [18] and below wolfberry (83%) [19] when compared with some traditional medicines. Despite quantitative differences, the proportions in total amino acids were consistent, making both ideal proteins for health food development and medicinal dietary combinations.

3.2 Analysis of Fatty Acid Nutritional Value

The two key indicators for measuring oil nutritional value are unsaturated fatty acid content and essential fatty acid content [20-21]. Linoleic acid and linolenic acid cannot be synthesized by the human body and must be obtained from food; deficiency leads to dermatitis, growth retardation, and other symptoms [22-23]. In this study, unsaturated fatty acids accounted for approximately 60% of total fatty acids in both duck and goose fatty liver, serving as essential fatty acids and providing important health benefits when consumed appropriately.

The ratios of saturated:monounsaturated:polyunsaturated fatty acids were 11.49:15.47:1.00 in duck fatty liver and 5.53:7.69:1.00 in goose fatty liver, with goose fatty liver containing higher linoleic and linolenic acid contents. This indicates that goose fatty liver oil composition more closely approaches the recommended human dietary intake ratio of 1:1:1.

Duck fatty liver contained significantly lower palmitic acid and significantly higher stearic acid than goose fatty liver. Palmitic acid can increase blood lipids and potentially raise blood cholesterol, while stearic acid has low digestibility and readily undergoes unsaturation to convert to oleic acid, which does not raise cholesterol, thus minimizing nutritional concerns.

3.3 Analysis of Texture Characteristics

Texture characteristics reflect meat tenderness and elasticity, serving as primary evaluation indicators for meat consumption. For fatty liver, which is highly tender and susceptible to processing changes, texture is particularly important for quality assessment. Reduced chewiness results from decreased hardness, weakened intercellular cohesion, and reduced elasticity. Sun [24] demonstrated that crude fat, fatty acids, springiness, lightness, and yellowness values in goose fatty liver increased with liver weight, while moisture, crude protein, hardness, and redness values decreased.

Sun [24] also established a quality grading system for goose fatty liver using eight macro-indicators (fat, moisture, protein, hardness, springiness, lightness, redness, and yellowness) with a two-step clustering method, confirming the optimal number of categories as four using Bayesian information criteria. Euclidean distance clustering analysis of 11 goose fatty liver groups classified them into four grades: Grade 1 (>800 g), Grade 2 (600-800 g), Grade 3 (300-600 g), and Grade 4 (300 g). Considering production practices, the optimal feeding period for goose fatty liver is 28-30 days, yielding the highest unsaturated fatty acid content and optimal liver-to-feed ratio, while for duck fatty liver it is 14-16 days.

Overly short feeding periods produce poor-quality liver, while overly long periods significantly increase mortality. This study demonstrates that at optimal feeding times, goose fatty liver exhibits lower hardness, higher adhesiveness, and better springiness compared to duck fatty liver, indicating superior tenderness and elasticity in market-available goose fatty liver.

4 Conclusions

1. Duck and goose fatty liver share the same amino acid types but differ in content. The EAAI values were 64.34 for duck and 60.25 for goose fatty liver; SRC values were 73.34 for duck and 47.11 for goose fatty liver. Goose fatty liver contained slightly higher proportions of taste amino acids, while duck fatty liver contained higher therapeutic amino acid content. These results indicate that duck fatty liver has superior amino acid nutritional value compared to goose fatty liver.
2. Goose fatty liver contained 61.70% unsaturated fatty acids and 39.31% saturated fatty acids, while duck fatty liver contained 59.11% unsaturated fatty acids and 41.25% saturated fatty acids. The saturated:monounsaturated:polyunsaturated fatty acid ratio in goose fatty liver was 5.53:7.69:1.00, approaching the recommended human dietary ratio. This indicates that goose fatty liver has superior fatty acid nutritional value compared to duck fatty liver.
3. Goose and duck fatty liver showed significant differences in hardness and adhesiveness. Goose fatty liver demonstrated better tenderness, while duck fatty liver exhibited higher hardness.

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Note: Figure translations are in progress. See original paper for figures.