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Phytochemical composition and nutritional characterization of qamgur (Brassica rapa L.) in different forms

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Abstract

The purpose of this paper is to determine the phytochemical composition and evaluate the nutritional value of qamgur (Brassica rapa L., a characteristic crop in Xinjiang). The fresh qamgur was processed with hot air drying and freeze drying and then sliced into FD qamgur slices and ground into qamgur powders. The results show that qamgur powders and FD qamgur slices are rich in the nutrients essential for human health, such as total sugar (41.4 and 44.8 g/100 g), polysaccharide (16.3×10^3 and 20.4×10^3 g/100 g), Vitamin C (39.3 and 46.5 g/100 g), flavonoids (45.0 and 33.0 g/100 g) and total saponins (46.0 and 30.0 g/100 g) compared with the fresh qamgur. Moreover, major elements and micro elements analysis were measured by inductively coupled plasma atomic emission spectrometry (ICP-AES), and the results showed that an abundant number of mineral elements (e.g. K, Na, Ca, Mg, Cu, Fe, Zn and Mn) were found in qamgur. The content of Ca was 4.5×10^3 mg/kg, 15.7 mg/kg for Zn, and 81.1 mg/kg for Fe. Similarly, the highest protein value was observed in the qamgur powders (12.4 g/100 g), whereas the fresh samples contained only 2.78 g/100 g. In addition, the proportion of essential amino acids (EAA) and nonessential amino acids (NEAA) of the powders were 59.7% and 40.3%, whereas for the FD slices, they were 61.0% and 39.0%. Overall, the nutritional value of qamgur was significantly improved through processing. So, in this paper, we provide the theoretical basis for the study on the nutritional value of qamgur and the development of medicinal foods and functional foods.

Keywords: qamgur; phytochemical composition; nutritional value; powder; freeze-dried.

Practical Application: As a traditional "medicine food homology" vegetable in China, the fresh qamgur being processed into commodities (qamgur powders and FD slices). Which can not only be better stored, but also increase and diversify the consumption. Moreover, qamgur powders and FD slices possess abundant phytochemical composition and nutritional value, such as flavonoid, saponin, amino acids, micro-elements, major-elements etc. So, this research provide the theoretical basis for the study on the nutritional value of qamgur (Xinjiang characteristic crop) and the development of medicinal foods and functional foods.

1 Introduction

In recent years, with the improvement of living standards and the rapid growth of industry, environmental pollution has become more and more serious. Exposure to ambient air pollution, toxic chemicals, and water pollution has been the problems that cause human diseases, such as cancer (Suk et al., 2016). Thus, people pay more and more attention to health and food safety. As we all know, a healthy dietary regime rich in fruits and vegetables can reduce the risk of diseases.

Qamgur (Brassica rapa L.) is also known as turnip (Gao et al., 2017), a very popular crop that has been widely planted around the world, especially in Xinjiang, where qamgur is widely cultivated and the favorite food for the Uygurs in Xinjiang. Besides, it is favored by people of all ethnic groups in northwest of China as a traditional and significant medicinal vegetable (Zhuang et al., 2019; Xue et al., 2020). The main reason is that qamgur is not only a vegetable, it possesses a wide array of biological and medicinal properties for controlling various diseases as well (Gaba et al., 2021; Paul et al., 2019), for example, some nutritional ingredients (soluble sugars, carbohydrates, lipids, protein, vitamins, minerals, organic acids, fatty acids) and phytochemical components of medicinal value (glucosinolates, isothiocyanates, flavonoids, phenolics) (Xue et al., 2020; Dejanovic et al., 2021; Klopsch et al., 2017; Chihoub et al., 2019). Turnips have always received much attention for their high nutritional value and excellent functional phytochemicals. Mohsen Gavahian (Farahnaky et al., 2018) showed that the phenolic and total flavonoids content of turnip are 865.835 ± 68.24 and 77.42 ± 8.67 mg/kg respectively. Helland's (Helland et al., 2016) results revealed that the vitamin C content of fresh turnip was 106.3 ± 2.7 mg/kg. Moreover, the fructose and glucose content of raw turnip were 40.6 and 51.9 g% against sucrose of 7.6 g% (Rodríguez-Sevilla et al., 1999). Proteins and amino acids contribute to the nutritive value and flavour of foods (Martínez et al., 2010). According to the study of Li et al. (2018) the main nutrient component, the content of total amino acids was 51.14 ± 1.36 g/kg in the fleshy turnip roots. In summary, the phytochemical composition of turnip is very rich and the nutritional value is very high, thus it attracts the extensive attention of researchers. In practice, large quantities of qamgur are normally consumed after being boiled in the preparation of soups and stews (Chihoub et al.,

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2019). However, fresh vegetables are not easy to store and can cause potential safety problem if they are left for a long time. Thus, poor storability is the largest problem that hinders the marketization of fresh qamgur (Huang et al., 2022).

So, it is essential that in the field of food processing, the qamgur be sliced and dried, ground into powders or even pickled. At present, freeze drying (FD) is the drying method that produces high-quality dehydrated foods with more added values, which conforms to the current food development trend of green, convenient, nutritious, and safe (Fan et al., 2020, p. 1). Herein, in our work, we analyzed and comprehensively evaluated the nutritional quality of fresh qamgur, qamgur powders and freeze dried (FD) qamgur slices. The results have provided valuable information about the nutritional value of qamgur and will provide futher a new idea for effective utilization of qamgur.

2 Materials and methods

2.1 Materials

All chemical solvents and standard substances were of analytical grade. The fresh roots of qamgur were harvested by Xinjiang Ailinur Agricultural Science and Technology Development Co., LTD, KePing area, Xinjiang. Yellowish-brown qamgur powders were produced in a dryer at a temperature of 60 °C and kept for 4-6 days. Freeze dried qamgur slices (FD slices) were homemade in the laboratory under an ultra-low temperature environment (-40 °C) and kept for 2-3 days. Powders and FD slices were stored at room temperature for future use.

2.2 Physicochemical analysis

Determination of moisture content

Determination of moisture content by the standard method (GB 5009.3-2016, National Standard of China). First, aluminum dish and sea sand were dried at 105 °C until constant weight was stabilized (m_3). 5 g of samples were placed in the aluminum dish and weighed along with sea sand (m_1). In order to ensure uniform distribution of the sample, the dish was shaken gently and then placed in the oven to be dried at 105 °C for 4 hours. What was followed was to move the samples to the desiccator and cool it to room temperature.Then the dish was again dried for 1h in the oven at the same temperature. Finally, it was removed to cool, and the dish and the dried samples were weighed (m_2).

The moisture content Formula 1 is as follows:

$$\%\,moisture = \left[\left(m_1 - m_2\right) / m_1 - m_3\right] \times 100 \tag{1}$$

Where, m_1 is the sum of final weight of dish, sea sand and samples before drying. m_2 is the sum of final weight of dish, sea sand and samples after drying. m_3 is the sum of final weight of dish and sea sand.

Determination of crude fiber

Crude fiber is called so because it exists in the bulk of food roughage. The content of crude fiber was determined by enzymatic gravimetric method in GB 5009.88-2014 (National Standard of China) (Li et al., 2020).

Determination of polysaccharide, reducing sugar and total sugar

The polysaccharide content was determined by the phenol-sulfuric acid method according to the literature (Guo et al., 2012). The content of reducing sugar and total sugar were determined according to the direct titration method in GB 5009.7-2016 and GB 5009.8-2016 (Sun et al., 2019) of National Standard of China respectively. The procedure was performed as follows: 10.000 g of samples were accurately weighed and placed in a 250 mL conical flask with 100 mL of deionized water in it and sedimented at a temperature at 40 °C for 60 min. 5 mL of Zn $(CH_3COO)_2 \cdot 2H_2O$ (21.9 g/mL) and 5 mL of $K_4\,[Fe(CN)_6] \cdot 3H_2O$ (10.6 g/mL) were added then and the mixed samples were separated by the filter. Then 25 mL of mixture was transferred into a 100 mL bottle and 5 mL hydrochloric acid (50%) was added. The mixture was heated to 70 °C and maintained for 15 min. The methyl red as indicator was added into the bottle and the mixture was adjusted to a neutral pH using 30% of sodium hydroxide solution. Afterwards, basic copper tartrate solution (A: dissolve 15 g of $CuSO_4 \cdot 5H_2O$ and 0.05 g of $C_{16}H_{18}ClN_3S \cdot 3H_2O$ in the distilled water and dilute to 1000 mL; B: dissolve 50 g of $C_4H_4O_6KNa \cdot 4H_2O$, 75 g of NaOH and 4 g of $K_4Fe(CN)_6 \cdot 3H_2O$ in the distilled water and dilute to 1000 mL) was successively added. Moreover, 10 mL of deionized water was added to the conical flask. Finally, the conical flask was brought to the titration stand and titrated until the blue color disappeared. Titrant of reducing sugar and total sugar were glucose standard solution.

The reducing sugar Formula 2 is as follows:

$$X = \left\{m_1 / \left[m \times F \times \left(V / 250\right) \times 1000\right]\right\} \times 100 \tag{2}$$

X is the content of reducing sugar (g/100 g), m_1 is the quantity of the reducing sugar used that titrated the basic copper tartrate solution (mg) ; V is the consumption volume of sample solution (mL); m is the quantity of sample (g), F is 0.8.

The total sugar value of the samples was calculated according to the formula shown in the Equation 3:

$$R = \left[A / \left(m \times V\right)\right] \times 100 \tag{3}$$

R is the content of total sugar (g/100 g); A is the quantity of glucose; m is the quantity of sample (g); V is the consumption volume of sample solution (mL).

Determination of Vitamin C

The content of vitamin C was determined using the 2,6-dichloroindophenol (2,6-D) solution titration method in GB 5009.86-2016 (Chinese standard method). The titer of 2,6-D was calculated using standard L(+)-ascorbic acid solution. 2, 6-D solution and L(+)-ascorbic acid solution in the sample were subjected to oxidation-reduction reaction. In the end of the reaction,the solution turned pink and the color held for 15 s. The blank test was carried out using the metaphosphoric acid solution instead of the sample.

Determination of ash content and elemental composition content

Ash content was measured according to GB 5009.4-2016 (Code of National Standard of China, Peng et al. 2021). Moreover, mineral macro-elements (P, K, Na, Ca and Mg) and micro-elements (Zn, Fe, Cu and Mn) were extracted using the microwave-assisted digestion. The reaction vessels were cleaned before each digestion using 5 mL of HNO_3 (Concentration: 65%), heated for 30 min in the Microwave Digestion System. The procedure was performed as follows: first, 0.1g of samples was accurately measured and added with 9 mL HNO_3 and the product was digested in the microwave digestion machine for 4 hours. The samples and blanks were heated on the graphite block at 110 °C for 3-4 hours (or until the samples were reduced to 1-2 mL in volume). After cooling, each extract was delivered with deionized water to a 25 mL volumetric flask. Finally, the content of K, Na, Ca, Mg, Zn, Fe, Cu and Mg was measured through the inductively coupled plasma atomic emission spectrometry (ICP-AES, 6000ICP, Germany LEEMAN Technology Instrument Co., LTD) at 766.5 nm, 589.6 nm, 422.7 nm, 285.2 nm, 213.9 nm, 248.3 nm, 324.8 nm and 257.6 nm respectively. Moreover, the content of P was determined by a spectrophotometer (U-3010 UV/vis spectrophotometer, Hitachi Corporation, Tokyo, Japan) at 660.0 nm.

Determination of protein and amino acids

The content of protein and amino acids was determined by the Method I Kjeldahl method in GB 5009.5-2016 (Liu et al., 2021) and acid hydrolysis method in GB 5009.124-2016. Acid hydrolysis method was in the following procedures: 10 mL of HCl (6 mol/L) was added into 0.2 g sample to be ultrasonic processed for 2 min, and the mixture was put in a stove and heated at 110 °C for 24 h. Then it was transferred to a 50 mL volumetric flask and diluted to volume with purified water. Finally, 1 mL of mixture was mixed with 5 mL HCl (0.02 mol/L), and it was filtered through a 0.22 μm inorganic filter membrane and determined by the Hitachi L-8900 amino acid analyzer (Hitachi, Tokyo, Japan).

Determination of flavonoids and saponin

2.00 g of qamgur sample was added with 50.0 mL ethanol (80%), after which, the sample was shaken for 3 min and performed in the ultrasonic for 45 min before filtration. Then 0.3 mL of 5% sodium nitrite solution was added into 3 mL of mixture which was mixed for 5 min on the vortex mixer, followed by the addition of 0.3 mL 10% aluminum nitrate solution. After 6 min, 2 mL of 1 mol/L sodium hydroxide solution was added. Finally, the mixture was further diluted with 30% ethanol and absorbance was measured at 490 nm. The flavonoid content was calculated and expressed as rutin equivalents. Moreover, the saponin content of qamgur was determined by HPLC analysis (Wang et al., 2012).

3 Results and discussion

Color is the most important sensory attribute perceived by the consumer and grower (Yousaf et al., 2021). In general, Fresh qamgur is white with globular roots, qamgur powders is yellowish-brown powders after low temperature drying, and FD qamgur slices appear in white flakes via ultra-low temperature and vacuum environment, as is shown in Figure 1.

The partial physiochemical properties of qamgur are shown in Table 1. Moisture content (Table 1) measurement is an important analysis performed on food product. Moisture plays a role in food quality, preservation and resistance to deterioration (Nielsen, 2009). Moisture content of fresh qamgur (82.8 g/100 g) was apparently higher than qamgur powders and FD qamgur slices (11.6 and 9.7 g/100 g). However, due to

Figure 1. The picture of fresh qamgur, qamgur powders and FD qamgur slices.

Table 1. The physiochemical properties of fresh qamgur, qamgur powders and FD qamgur slices.

Physicochemical properties	Fresh qamgur	Qamgur powders	FD qamgur slices
Moisture (g/100 g)	82.8 ± 0.1[a]	11.6 ± 0.1[b]	9.7 ± 0.0[c]
Crude fibre (%)	1.2 ± 0.0[b]	5.6 ± 0.1[a]	0.9 ± 0.0[c]
Reducing sugar (g/100 g)	3.4 ± 0.1[c]	27.5 ± 0.1[b]	33.1 ± 0.1[a]
Invert sugar (g/100 g)	7.0 ± 0.1[c]	41.4 ± 0.2[b]	44.8 ± 0.3[a]
Total sugar (g/100 g)	2.9×10^3 ± 5.0[c]	16.3×10^3 ± 5.3[b]	20.4×10^3 ± 6.7[a]
Vitamin C (mg/100 g)	67.3 ± 0.5[a]	39.3 ± 0.0[c]	46.5 ± 0.3[b]
Flavonoid (mg/100 g)	6.7 ± 0.1[c]	45.0 ± 0.1[a]	33.0 ± 0.1[b]
Total saponins (mg/100 g)	4.0 ± 0.0[c]	46.0 ± 0.6[a]	30.0 ± 0.2[b]

The values are expressed as the mean value ± standard derivation (n = 3).

high moisture content of qamgur, they have very short storage time and are liable to spoil (Lal Basediya et al., 2013). So fresh roots of qamgur were processed into powders and FD slices. Alessandra (Di Bella et al., 2021) deemed that crude fiber could increase the bulk and speed up the passage of food through the alimentary tract, and therefore reduce the absorbtion of toxic substances. The crude fiber content of fresh qamgur, powders and FD slices are represented in Table 1 and they are detected at 1.2%, 5.6% and 0.9% respectively.

The data of reducing sugar content, total sugar content and polysaccharide content are shown in Table 1. It can be found that the content of reducing sugar, total sugar and polysaccharide in the powders and FD slices are higher than fresh qamgur. Meanwhile, the content of reducing sugar, total sugar and polysaccharide in the FD slices are the highest, about 33.1, 44.8 and 20.4×10^3 g/100 g. One reason is due to the moisture loss, another is the longer process that FD process need to dry the samples, which also can cause more starch to get hydrolyzed to become sugar (Jiang et al., 2010; Orak et al., 2012). Moreover, sugar content is a very important factor that contributes to the taste, texture and overall attraction of the fruits and vegetables (Song et al., 2015), since most people usually prefer sweeter foods. Therefore, people prefer the texture and taste of FD slices than qamgur powders.

It is well known that Vitamin C is an important and essential nutrient for humans who get antioxidant from eating fresh fruits and vegetables to be immune from human diseases. Vitamin C can also be regarded as an index of processed nutrient quality. We can see from Table 1 that the vitamin C content of fresh qamgur is the highest at 67.3 mg/100 g. But during the processing, the content of vitamin C decreased markedly due to temperature and moisture content. Vitamin C content of FD slices (46.5 mg/100 g) was significantly higher than the powders (39.3 mg/100 g), maybe it is because FD slices maintain an optimal bio-compound content at low temperatures (Bhatta et al., 2020).

As is well-known that flavonoids possess a broad spectrum of health-promoting effects due to their anti-oxidative, anti-inflammatory, anti-mutagenic and anti-carcinogenic properties coupled with their capacity to modulate key cellular enzyme functions (Panche et al., 2016). The flavonoids content of fresh qamgur, powders and FD slices are 6.7, 45.0 and 33.0 mg/100g respectively (Table 1). The flavonoids quantity increased about 6.7 folds and 4.9 folds in the powders and FD slices compared with fresh qamgur. The possible reason is that flavonoid compound could evaporate easily during heating (Kim et al., 2013). Similarly, total saponins also act as a powerful antioxidant and effect against anticarcinogenic activities etc. The total amount of saponins increased from 4.0 mg/100g to 46.0 mg/100g using different processing methods (Table 1). At the view of the results, the presence of vitamin C, flavonoids and total saponins in qamgur might be directly related to some of its medicinal properties. This result further proves the "medicine and food homology" effect of qamgur.

The results of the content of ashes and individual elements in fresh qamgur, powders and FD slices are detailed in Table 2. Ash content of qamgur, qamgur powders and FD qamgur slices are 1.34 g/100 g, 7.31 g/100 g and 1.24 g/100 g respectively. The result shows that processing methods insignificantly affect the ash content of all the samples.

Elemental analysis of vegetables is an important research that assesses the nutritional value and mineral content of food and evaluates the toxic micro-elements. Moreover, food quality is related to the content and type of minerals that contribute to taste, appearance, texture and stability (Rodrigues et al., 2022). Major elements including phosphorus (P), calcium (Ca), magnesium (Mg), potassium (K) and sodium (Na) etc. Two of which (K and Na), as an important electrolyte, are important for the human nervous system, muscle function, fluid balance and heart, kidney and adrenal functions when taken appropriately (Juranović Cindrić et al., 2012). Among these elements, K notoriously represents the most abundant mineral of 34.5, 124 and 170 mg/kg in the fresh qamgur, powders and FD slices and is respectively higher than Na content (18.8, 95.3 and 87.1 mg/kg). The results are shown in Table 2 and Figure 2a. Similarly, Ca plays a key role in bone and tooth formation, blood clotting, muscle contraction and nerve transmission. So the adequate intake of calcium is significant for bone health. It is obvious that 4500 mg/kg in the FD slices is higher than the powders and fresh qamgur (3010 mg/kg and 460 mg/kg), as shown in Table 2 and Figure 2a. Magnesium's role on the body is similar to that of calcium, for example, its function is to regulate demic angiotasis, heart rhythm, platelet-activated thrombosis and bone formation

Table 2. Ash Content and elemental composition of fresh qamgur, qamgur powders and FD qamgur slices.

parameter	Fresh qamgur	Qamgur powders	FD qamgur slices
Ash (g/100 g)	1.34 ± 0.00^b	7.31 ± 0.05^a	1.24 ± 0.02^c
P (mg/kg)	6.3 ± 0.1^c	33.1 ± 0.6^b	40.8 ± 0.7^a
Ca (mg/kg)	466 ± 1.7^c	$3.02 \times 10^3 \pm 0.58^b$	$4.51 \times 10^3 \pm 0.57^a$
Mg (mg/kg)	326 ± 2.6^c	$1.95 \times 10^3 \pm 2.5^b$	$1.98 \times 10^3 \pm 3.8^a$
K (mg/kg)	34.5 ± 0.1^c	$0.124 \times 10^3 \pm 3.2^b$	$0.17 \times 10^3 \pm 3.6^a$
Na (mg/kg)	18.8 ± 0.1^c	95.3 ± 0.1^a	87.1 ± 0.4^b
Zn (mg/kg)	3.2 ± 0.1^c	19.0 ± 0.6^a	15.7 ± 0.2^b
Fe (mg/kg)	9.0 ± 0.2^c	77.6 ± 0.5^b	81.1 ± 1.3^a
Cu (mg/kg)	0.46 ± 0.00^c	2.56 ± 0.04^b	3.26 ± 0.01^a
Mn (mg/kg)	1.62 ± 0.02^c	7.69 ± 0.00^b	9.7 ± 0.01^a

The values are expressed as the mean value ± standard derivation (n = 3).

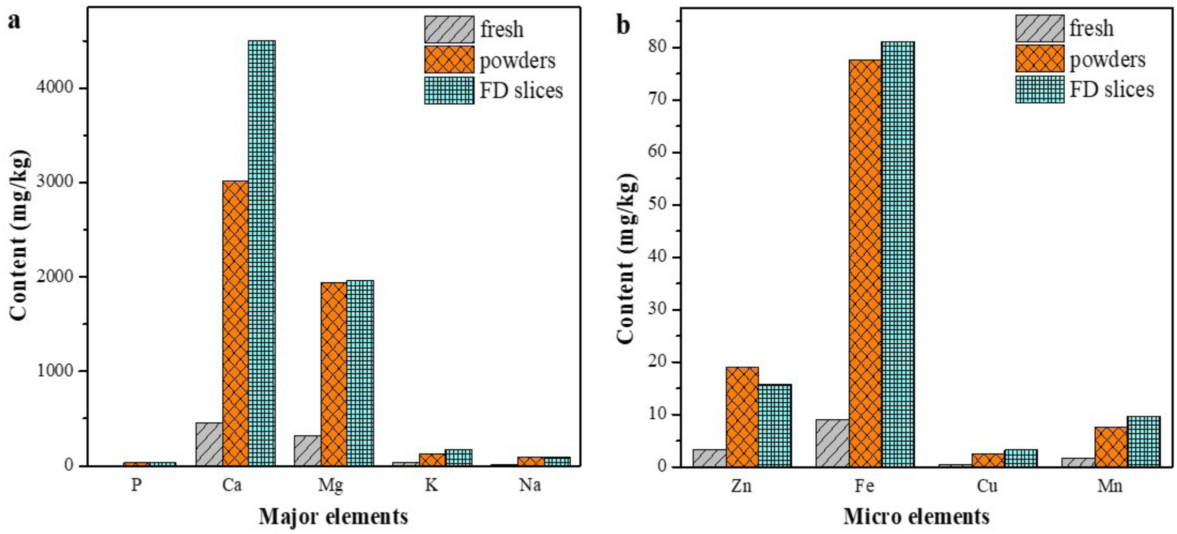

Figure 2. (a) the content of major elements and (b) micro elements of fresh qamgur, qamgur powders and FD slices.

(Jahnen-Dechent et al., 2012; Juranović Cindrić et al., 2012;). The content of Mg is 324, 1940 and 1960 mg/kg respectively in the fresh qamgur, powders and FD slices (see also Table 2 and Figure 2a). Moreover, as an essential mineral, phosphorus (P) is required for cell structure, signaling, energy transfer, and other important functions. Thus, moderate phosphorus intake can have beneficial consequences on the skeletal, renal, and cardiovascular systems (Chang & Anderson, 2017). The results shown in Table 2 and Figure 2 tell that fresh qamgur had lower content of P about 6.3 mg/kg, however, processed qamgur products exhibited a high content of P at 33.1 mg/kg and 44.8 mg/kg (powders and FD slices).

Micro-elements zinc (Zn), Iron (Fe), copper (Cu), and manganese (Mn) have the most practical significance in agriculture and human health. The lack of micro-elements in human diet can weaken several functions of the central nervous system, reproductive system, enzyme activities and energy metabolism and thus cause serious diseases (Nieder et al., 2018). It is vital that zinc (Zn) be involved in metabolism and cell growth as a co-factor for certain enzymes. Because most enzymes are involved in redox reaction, for example, metabolism of proteins, carbohydrates, lipids, and energy etc. Zn content of qamgur powder was 19.0 mg/kg, however, only 3.2 mg/kg in the fresh qamgur and 15.7 mg/kg in the FD slices (see Table 2 and Figure 2b). In the human body, more than half of Fe is combined with hemoglobin and so an obvious outcome of Fe deficiency is anemia (Clemens, 2014; Al-Fartusie & Mohssan, 2017). It's worth noting that the content of Fe in the FD slices is 81.1 mg/kg, which is about 9-fold that of the fresh qamgur (see Table 2 and Figure 2b). Copper (Cu) can help with the Fe incorporation into hemoglobin, assist the absorption of Fe from the gastrointestinal tract, and accelerate the transfer of Fe from tissues to the plasma (Al-Fartusie & Mohssan, 2017). Furthermore, the research recommended the daily intake amount of 2 mg of Cu per day for healthy adults in general. As shown in Table 2 and Figure 2b, Cu content of the FD slices is 3.26 mg/kg, while the content of the powder is 2.56 mg/kg and 0.46 mg/kg in the fresh qamgur. Mn is one of the most important elements in human, since it helps the body to form connective tissues, bones, blood-clotting factors, and sex hormones. Nonetheless, when the intake exceeds the normal level or is below it, it would cause diseases, such as neurological disorders, hypercholesterolemia, skeletal abnormalities and etc. (Al-Fartusie & Mohssan, 2017). Mn content of FD slices and powders in the finished study is 9.7 mg/kg and 7.69 mg/kg respectively (see Table 2 and Figure 2b). Therefore, it is the cheapest and most efficient way for us to get micro-elements from fruits, vegetables and meat in our daily life.

As a matter of fact, plants can synthesize the biomolecules (such as amino acids and protein) in their own body through absorbing mineral elements, air and water. However, the humans and animals cannot synthesize essential organic molecules and thus these essential amino acids and protein have to be acquired from the diets.

Proteins is regarded as the most important macro-nutrient for humans, which can provide energy but it is also extremely important for the growth and development of children. The content of proteins of fresh qamgur, powders and FD slices are respectively 2.78, 12.4 and 9.4 g/100g (see Table 3). Moreover, amino acids is also found in the natural plants. For animals and humans, amino acids(AA) has traditionally been classified as nutritionally essential (EAA) and nonessential (NEAA). However, nonessential amino acids plays an essential role in regulating gene expression, intracellular protein turnover, nutrient metabolism, and oxidative defense (Wu, 2010). Indeed, amino acids deficiency causes serious diseases both in humans and animals. Likewise, only a few papers have examined the amino acids content of qamgur.

In this context, we provided the content of 16 amino acids of qamgur. As shown in Table 3 and Figure 3, total amino acids of

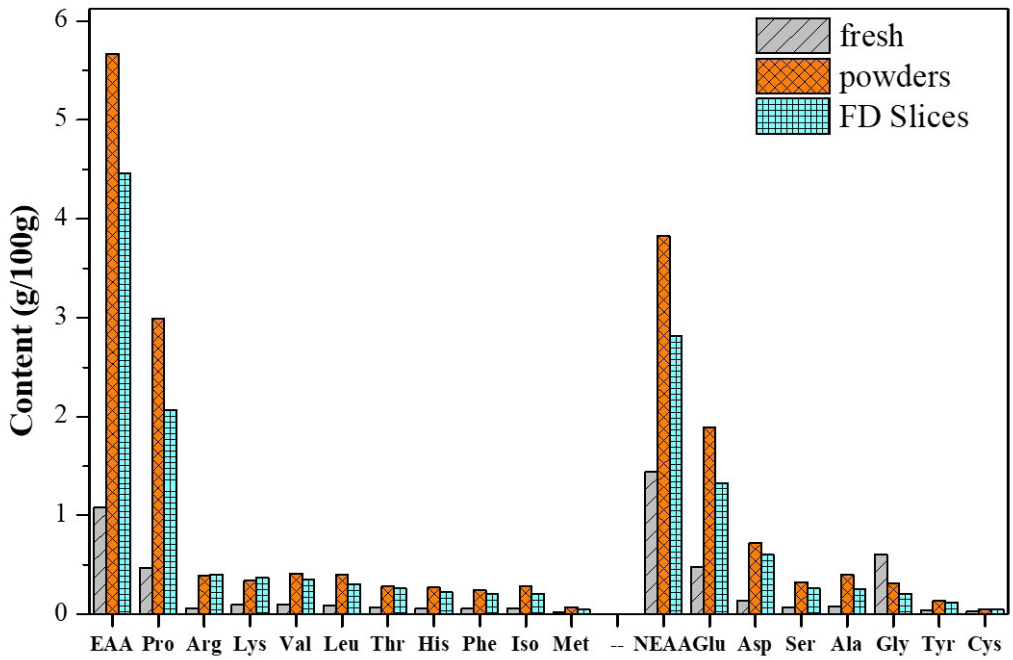

Figure 3. Amino acids content of fresh qamgur, qamgur powders and FD qamgur slices.

Table 3. Protein and amino acids content of fresh qamgur, qamgur powders and FD qamgur slices.

parameter	Fresh qamgur	Qamgur powders	FD qamgur slices
protein (g/100 g)	2.8 ± 0.0[c]	12.4 ± 0.0[a]	9.4 ± 0.0[b]
Aspartic (g/100 g)	0.142 ± 0.005[c]	0.723 ± 0.015[a]	0.601 ± 0.025[b]
Tyrosine (g/100 g)	0.039 ± 0.001[c]	0.140 ± 0.006[a]	0.120 ± 0.000[b]
Serine (g/100 g)	0.074 ± 0.004[c]	0.320 ± 0.015[a]	0.260 ± 0.015[b]
Glutamic (g/100 g)	0.480 ± 0.024[c]	1.890 ± 0.050[a]	1.330 ± 0.060[b]
Glycine (g/100 g)	0.060 ± 0.002[c]	0.310 ± 0.010[a]	0.210 ± 0.010[b]
Alanine (g/100 g)	0.081 ± 0.004[c]	0.400 ± 0.006[a]	0.250 ± 0.010[b]
Cystine (g/100 g)	0.026 ± 0.002[c]	0.052 ± 0.002[a]	0.049 ± 0.006[b]
Valine (g/100 g)	0.099 ± 0.003[c]	0.410 ± 0.010[a]	0.350 ± 0.010[b]
Methionine (g/100 g)	0.018 ± 0.001[c]	0.072 ± 0.005[a]	0.046 ± 0.007[b]
Isoleucine (g/100 g)	0.061 ± 0.003[c]	0.280 ± 0.006[a]	0.200 ± 0.006[b]
Leucine (g/100 g)	0.092 ± 0.002[c]	0.400 ± 0.010[a]	0.300 ± 0.006[b]
Threonine (g/100 g)	0.064 ± 0.003[c]	0.280 ± 0.006[a]	0.260 ± 0.015[b]
Phenylalanine (g/100 g)	0.058 ± 0.002[c]	0.240 ± 0.006[b]	0.290 ± 0.006[a]
Histidine (g/100 g)	0.059 ± 0.002[c]	0.270 ± 0.010[a]	0.220 ± 0.006[b]
Lysine (g/100 g)	0.096 ± 0.006[c]	0.340 ± 0.006[b]	0.370 ± 0.010[a]
Arginine (g/100 g)	0.061 ± 0.002[c]	0.390 ± 0.020[b]	0.400 ± 0.015[a]
Proline (g/100 g)	0.468 ± 0.011[c]	2.990 ± 0.085[a]	2.070 ± 0.110[b]
Total amino acids (g/100 g)	1.978 ± 0.005[c]	9.504 ± 0.133[a]	7.235 ± 0.012[b]

The values are expressed as the mean value ± standard derivation (n = 3).

qamgur powders was the highest at 9.504 g/100g compared with FD slices and fresh qamgur (7.235 g/100 g and 1.978 g/100 g). Proline of powders is the essential amino acids, accounting for 31.5% of the total amino acids, followed by valine (4.3% of the total AA) and leucine (4.2% of the total AA). And the other major types of amino acids of powders are arginine, lysine, and threonine. Moreover, proline also has the highest proportion of fresh qamgur and FD slices, accounting for 23.7% and 28.6% of the total amino acids. However, in addition to proline, the other important types of amino acids of FD slices are arginine (5.5%), lysine (5.1%) and valine (4.8%). Meanwhile, for fresh qamgur, the major types of amino acids are valine (5.0%), lysine (4.9%) and leucine (4.7%).

So far, the hypothesis that "nonessential amino acids" is synthesized adequately in the body to meet the needs for human growth and health has not been verified by researchers after relevant experiments (Wu et al., 2012). Therefore, nonessential amino acids as an indispensable part of amino acids has attracted extensive attention of researchers. In the qamgur powders and FD slices, the content of glutamic was as high as 1.890 g/100 g (19.9% of the total AA) and 1.330 g/100 g (18.4% of the total AA), followed by aspartic acid (7.6% and 8.3%). In fact, the provision of energy for the small intestines through glutamic acid and aspartic acid can enhance the wriggle of small intestines (Hou et al., 2015). Moreover, glycine and serine participate in the metabolism of single carbon. All in all, both essential and non-essential amino acids is the important component involved in the normal operation of life.

4 Conclusion

Qamgur, as a traditional and significant "medicine and food homology" vegetable, was studied depend on the phytochemical composition analysis and the nutritional characterization analysis in this experimental study. The results indicate that the nutritional value of the qamgur powders and FD slices are higher than the fresh qamgur. Analysis on the physiochemical properties show a significant effect of antioxidant and antitumor activity due to the presence of Vitamin C, flavonoids and saponins. In addition, the determination of elemental composition indicate that qamgur powders and FD slices contain a significant number of major elements and micro-elements compared with fresh qamgur. Moreover, the processing method (hot air drying and freeze drying) can increase the content of proteins and amino acids of qamgur. In conclusion, the findings of this study not only improve people's understanding of the nutritional value of qamgur, but may also be helpful for the development of the Xinjiang characteristic crop - qamgur as medicinal food and functional food.

Conflict of interest

The authors declare that they have no conflicts of interest.

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