Traditional Tibetan Ghee: Physicochemical Characteristics and Fatty Acid Composition

Bingyu Jing¹, Wenjie Chen², Mengzhu Wang¹, Xiaohui Mao¹, Jia Chen¹, and Xiuzhu Yu¹*  
¹ College of Food Science and Engineering, Northwest A and F University, 22 Xinong Road, Yangling 712100, Shaanxi, P. R. CHINA  
² Hybrid Rape Research Center of Shaanxi Province, 6 West Gaogangqu Road, Yangling 712100, Shaanxi, P. R. CHINA

Abstract: Fifty traditional Tibetan ghee (TTG) varieties were collected and analyzed their systematic characteristic indices, including physicochemical parameters, minerals, fatty acid composition, and thermal behavior. Results show that TTG contains a large amount of fat (71.68%–93.3%) and a small quantity of protein (0.51%–1.81%). The acid and peroxide values of TTG vary from 0.02 to 1.30 mg/g and 0.07 to 5.93 meq/kg, respectively. The content of minerals varied with altitude level and region significantly (p < 0.05), and the regional variations of fatty acids in TTG were also observed significantly, these differences may be due to the high unsaturated fatty acids level in the cow diets.

Key words: traditional Tibetan ghee, physicochemical characteristics, minerals, fatty acid composition

1 Introduction

Ghee is a traditional Tibetan dairy product that is produced from a series of fermentation, heat clarification, and desiccation of yak milk. The yak is placed under the subfamily Bovine and belongs to the classification of Bos grunniens, which is mainly found in the highlands of Nepalese Himalayas, Indian Kasmir, Tibet, Mongolia, and Bhutan¹. The major constituents of yak milk are fat (6%–10%), protein (5.5%), lactose (5%), and minerals (1.1%)². Yak milk is increasingly recognized for its nutritional benefits and is included in products such as cheese, butter milk tea, and yogurt. Due to the attractive appearance, grainy and semisolid texture, pleasant odor, excellent taste, and the high proportion of polyunsaturated fatty acids (PUFAs)³, traditional Tibetan ghee (TTG) has important culinary purposes, such as dressing, cooking, frying, and even in religious rites. Many food manufacturers and research organizations also consider TTG as PUFAs resources to meet the increased consumer demand of PUFA-rich oils.

Over the past several years, various studies have been focused on the characteristics of TTG. Chassaing et al. investigated the European ghee with industrial ghee in terms of peroxide value, minerals, and vitamin A, but the numbers of samples are insufficient to determine the physico-chemical indicators in ghee varieties⁴. Moreover, many researches also focused on the functional properties in ghee. Silva et al. mainly studied the fatty acid composition, physicochemical characteristics, as well as microbiological properties, it indicated that ghee produced from cows’ milk based on grass-feeding have a potentially healthier fat content and a desirable flavour⁵. Neupane⁶ et al. studied some functional properties of yak butter lipids through analysis of conjugated linoleic acid (CLA) composition, differential scanning calorimetric (DSC) analysis, and determination of tyrosine inhibition activity and antioxidant property⁷. Orrashid et al. studied the fatty acid content of both domesticated and stocked cheese, indicating that cheese that grazed on Himalayan alpine pastures has a more balanced fatty acid composition⁸, however, to the best of our knowledge, the studies on characteristics of TTG were still lacking, while all of them are important parameters for processing and utilization. The main objectives of this study are to analyze the global character such as physicochemical characteristics, fatty acid composition and mineral content, Fourier transform infrared (FTIR) spectra, and thermal characteristics, most importantly, the relationship of geographical location with the content of minerals and fatty acid also studied in the paper.

2 Materials and Methods

2.1 Samples

The 50 ghee samples were collected from seven different Tibetan regions, Sannan (n = 12, 3700 m), Shigatse (n = 12, 4000 m), Lhasa (n = 9, 3650 m), Qamdo (n = 11, 3500 m),
Nagqu (n=2, 3000 m) and Ngari (n=4, 4500 m) respectively. All the yak milk were collected during mid-April period, the samples were stored and frozen (−18°C) before further analysis. The specific information of samples is presented in Table A. 3.

2.2 Physicochemical analysis

The acid value (AV) and peroxide value (PV) were determined according to the standard methods of American Oil Chemists’ Society (AOCS Official Method Cd 8b-90) (AOCS, 2003a). Briefly, the determination of PV mainly uses mixture of oil and chloroform/acetic acid, which was left to react with a solution of potassium iodide indarkness; the free iodine then titrated with a sodium thiosulfate solution. The determination of AV mainly uses mixture of oil and diethyl ether/ethanol added with 2 mL phenolphthalein. The mixture was titrated with 0.01 M of potassium hydroxide and shaken vigorously until the color was changed (from white to pink).

Moisture was determined according to AOCS Official Method 926.12, briefly, moisture content was determined from the loss of mass of a specified quantity of oil heated at 105 ± 1°C in a hot-air oven for 1 h, and crude fat and protein were determined according to the standard method of the Association of Official Analysis Chemists (AOAC Official Methods of Analysis, 15th, 1990). Protein content was calculated from nitrogen content as follows: N(%) × 6.25 using Kjeldahl’s method. The fat content was measured by using a Soxhlet extraction apparatus with petroleum ether as a solvent for 8 h. All analyses were carried out in triplicate.

2.3 FTIR spectra analysis

A Bruker VERTEX 70 series FTIR spectrometer (Bruker Optics, Germany) equipped with a deuterated detector was used to obtain the FTIR spectra. At the ambient temperature, a droplet of the sample was evenly smeared on the screen of 100 meshes and placed in the sample chamber of the FTIR spectrometer. The spectra were obtained from 6000 cm$^{-1}$ to 400 cm$^{-1}$ at a resolution of 8 cm$^{-1}$ by using 64 co-added scans. The background air spectrum was subtracted before analyzing the sample spectra.

2.4 Thermal characteristic analysis

The thermal characteristics of samples were determined with a modulated differential scanning calorimeter (DSC, TAQ20, USA). The instrument was calibrated using indium (156.6°C, 28.57 J/g) and zinc (419.5°C, 108 J/g). An empty DSC-pan was used as a reference. N$_2$ was used as the purge gas at a flow rate of 40 mL min$^{-1}$. The sample (6−9 mg) was accurately weighed directly on the DSC-pan (SFI-Aluminum, TA Instrument T11024). The sample was allowed to equilibrate at 80°C for 10 min after being heated to 80°C at a rate of 5°C min$^{-1}$. Then, it was held for 10 min before cooling to −30°C, held for another 10 min, followed by heating cycle to 80°C at the same rate. The cooling and heating cycle were repeated. The onset, peak, end temperatures, and the enthalpy of thermal transition (melting and crystallization) were determined through the acquired thermograms.

2.5 Mineral analysis

The analytical wavelengths (nm) chosen were: Al, Ca, Fe, Mg Na, Zn. For the operating conditions of the equipment, the radio frequency power (1.5 kW) and the plasma (15.0 L/min), auxiliary (0.4 L/min), and nebulizer (0.7 L/min) gas flow-rates were optimized from previous works. Single-element standard stock solutions containing 1000 mg/L Cu, Fe, Mn, Mo, and Zn and 4000 mg/L Ca, K, Mg, Na, and P were suitably diluted to prepare analytical calibration solutions. Elemental determination by ICP OES was performed using external calibration. The standard solutions for the calibration curves were prepared at the same acid concentration for each digestion procedure.

2.6 Fatty acid composition analysis

The fatty acid composition of TTG was determined through conventional saponification/methylation procedure. First, 60 mg of sample was mixed with 200 μL of 2% methanolic KOH in screw-capped glass tubes. The tubes were stirred for 5 min and held at room temperature for 30 s. After acidification with 1 g of NaHSO$_4$, the released fatty acids were extracted twice by using 4 mL of isooctane. Then, 2 mL of 5 mg/mL internal standard (C$_{11}$) was added into the fatty acid mixture and vortexed for 1 min at ambient temperature. The fatty acid methyl esters (FAMEs) were then extracted by the addition of 4mL of isooctane. This isooctane solution containing FAMEs was subjected to Gas chromatography–Flame Ionization Detector (GC–FID) analysis to quantify the fatty acids. Under the same detection conditions, the retention time of mono-fatty acid methyl ester was compared with the standard to identify the quality of fatty acids and with the area of each peak for the quantitative analysis. GC measurements were carried out on a fused-silica capillary column (HP-INNOWAX, 0.25 mm × 0.25 μL × 30 m). The temperature of the inlet was set at 250°C. After holding the sample at ambient temperature for 2 min, the oven temperature was increased to 240°C at 10°C min$^{-1}$ and maintained for 10 min. High-purity nitrogen was used as carrier gas at flow rate of 1.1 mL/min. One μL of sample was injected by the split mode injection system.

2.7 Statistical analysis

All experimental measurements were conducted at least in triplicate, and the data are expressed as mean ± standard deviation by using Microsoft excel 2010, Spss and Minitab software.
3 Results and Discussion

3.1 Physicochemical analysis

As shown in Table 1, chemical analysis revealed that the quality parameters such as AV and PV of TTG were 0.22 mg/g oil and 1.31 meq/kg respectively, and the PV of TTG is in the range for traditional Tunisian butter (1.12-1.67 meq/kg)\(^6\), which is slightly lower than that of Eastern Anatolian ghee (1.28-9.83 meq/kg)\(^7\), and the traditional East Algerian butter (1.60-3.01 meq/kg)\(^8\). The AV of TTG is lower than that of Qinghai ghee (1.23-5.51 mg/g). The low value indicates that TTG possesses lower quantities of free fatty acids (FFAs) and oxidation by-products. Findik et al. indicated that any oil with PV >15 meq/kg oil is considered unfit for human consumption\(^9,10\). Due to the high proportion of highly oxidation-sensitive PUFAs, a continuous increase in PV was observed in TTG during storage. Therefore, the protection of samples from possible oxidation degradation by incorporating antioxidants is essential to extend the shelf-life.

Fat is an important factor to determine the quality of oil. The crude fat in TTG varies from 71.68-93.39 g/100 g oil, which is slightly lower than the range of 90.11-99.01 g/100 g oil as reported for various ghee\(^10\), and the high proportion of fat will lead rancidity and generate rancid flavor when stored in unsuitable condition. Furthermore, the protein content was 1.06 g/100 g oil in the samples, which is within the range of 0.10-1.41 g/100 g oil as reported for various kinds of TTG\(^7\).

The moisture content in TTG is within 10.55-30.41 g/100 g oil, which is in the same range as East Algerian butter (17.50-26.01 g/100 g)\(^8\). High moisture in TTG can lead hydrolytic breakdown and generate rancid flavor.

3.2 Thermal characteristic analysis

DSC has been used to study the thermo-oxidative processes that occurred in the oil as a function of temperature and heat flow\(^11\). Figure 1 shows the thermal characteristics of TTG samples collected from the regions of Sannan, Lhasa, and Qamdo in Tibet. The crystallization peak was not prominent when cooled to -30°C, but when the oil was heated, the melting curve showed a broad peak from -30°C to 80°C. Moreover, the endothermic peak shows a broad range from 0-30°C rather than a sharp and intense peak, which is mainly due to the presence of the mixture of triglycerides\(^12\). During melting, the 3 samples show a similar broad exothermic peak on the melting curve from 10-20°C (Sanan), 15-23°C (Lhasa) and 10-35°C (Qamdo). The broadest exothermic peak range was observed in Qamdo ghee, which is mostly attributed to the management system, climate, season, and sampling periods\(^13\). The melting of triglyceride also depends on its chain length, extent of branching of the chain, the unsaturation of its constituent fatty acids as well as their stereo-specific distribution along the glycerol molecules\(^14\), and the melting point of oil increases with increasing chain length and saturation of constituent fatty acids\(^15\). As shown in Fig. 1, a sharp and intense peak appears at -15°C, indicating that TTG is a mixture rather than a pure semisolid.

3.3 FTIR spectra analysis

The characteristic peaks in FTIR spectra can specifically represent the common characteristic molecular features of oil\(^16\). Figure 2 presents the representative FTIR spectra of TTG, which were collected from the region of Sanan, Shigatse, Lhasa, and Qamdo in Tibet. The spectra in the high-wavenumber region present strong multiple bands. The 2975–2830 cm\(^{-1}\) range is assigned to C–H stretching of the methyl and methylene backbones of the lipids. The distinctive peak at 3468 cm\(^{-1}\) shown in the Fig. 2, was caused by the C-H stretching of C-O bonds. Commonly, this peak in higher wave-number region can be used to determine oxi-

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mean</th>
<th>Coefficient of variation (%)</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>AV (mg/g)</td>
<td>0.22</td>
<td>1.22</td>
<td>0.02</td>
<td>0.27</td>
</tr>
<tr>
<td>PV (meq/kg)</td>
<td>1.31</td>
<td>0.88</td>
<td>0.07</td>
<td>5.93</td>
</tr>
<tr>
<td>Fat (g/100 g)</td>
<td>82.54</td>
<td>0.06</td>
<td>71.68</td>
<td>93.39</td>
</tr>
<tr>
<td>Protein (g/100 g)</td>
<td>1.06</td>
<td>0.30</td>
<td>0.31</td>
<td>1.80</td>
</tr>
<tr>
<td>Moisture (g/100 g)</td>
<td>14.5</td>
<td>0.35</td>
<td>11.2</td>
<td>17.9</td>
</tr>
</tbody>
</table>

Fig. 1 DSC thermograms of TTG.

Table 1 Physicochemical characteristics of TTG\(^a\).

\(^a\) mean ± standard deviations.
similar results were reported by Cao et al. Minerals analysis lipids or oils. technique is an effective method to evaluate the quality of O carbonyl stretching of the ester functional groups of C
pasture sites and grass species. Moreover, the high unsaturation is mostly attributed to the regional weather, possesses the highest unsaturation, the regional difference shows the most intense stretching, which indicated that it
Calcium, as the largest content of macroelement, detected from west to east, other minerals such as Al, Mg, Fe, Zn
variations content of minerals also showed the significant regional variation. As studied, the concentration of minerals closely linked to the agrotype, moisture content and organic matter. Overall, all the highest concentration of minerals were found in Ngari, the local soil environment and vegetation may explain the high minerals level of TTG, the region which over 4500 meters are covered with the brushwood, prairie and shrub and the local soil are rich in the chernozem, alpine meadow soil, with the high content of organic matter, nitrogen, potassium content and so on, for another, the characteristics of plateau temperate monsoon arid climate, precipitation deficit also beneficial to maintain the minerals. While the minerals of Ca, Fe, Mg, Zn detected the lowest concentration in Lhasa, it was attribute to the local feature. One side, Lhasa located in the southeast of Tibetan region, which the altitude is over 3650 meters, the plateau temperate semi-arid monsoon climate, sandy loam, the low concentration of organic matter lead to the content of minerals is unstable.

The TTG samples subjected to multivariate analysis of variance (MANOVA) shows that the minerals in different altitude level showed the significant variation\((p<0.05)\). The results of the minerals based on the altitude level are visualized in the linear discriminant analysis (LDA) plot (Fig. 3a), the first discriminant function accounted for 72.4% of total variance and the second accounted for 27.6%. All of them account for 100% of total variance, which is very satisfactory. It is shown that there is an adequate separation in the three altitude levels (A1 to A3). More specifically, the first discriminant function differentiates the A1 (<3000 m), from A2 (4010-3200 m), the second discriminant function differentiates A2 (4010-3200 m) from A3 (5165-4010 m). As shown in Fig. 4a, calcium is the dominant minerals in TTG, in the altitude range of 3000 m to 5000 m, the content of Ca increased with altitude level higher significantly, the high concentration of organic matter, magnesiam and phosphorus in soil may explain the high level of calcium, related to a number of factors such as weather conditions, botanical composition of pasture and moisture content.

The TTG samples subjected to MANOVA shows that the minerals in different regions also showed the significant variation\((p<0.05)\). The results of the minerals based on
the regions are visualised in the LDA plot (Fig. 3b), the first discriminant function accounted for 80.5% of total variance and the second accounted for 19.5%, which is very satisfactory. It is shown that there is an adequate separation of the three groups (B1 to B3). More specifically, the first discriminant function differentiates B1 (Ngari, Lhasa) from B3 (Qamdo, Nagqu), the second discriminant function differentiates B1 (Ngari, Lhasa) from B2 (Ngari, Shigatse), the minerals classification based on the regions is mainly attributed to the significant variations in the physicochemical properties of soil in Tibet\textsuperscript{24}. In eastern Tibet, the average vegetation coverage is over 68.31%, and the local soil which composed of light and middle loam riched in organic matter (>9.16%), moreover, the high content of moisture (9.16%) and nitrogen (0.42%) in local soil is beneficial to maintain the minerals, the pH value (7.54) is lower than western Tibet (8.14). While in western Tibet, the local soil is over 60.11%, with the high degree of sand, moreover, the coverage of vegetation is deficient (< 28.90%), with a small number of organic matter (<2%) and nitrogen (< 0.21%), so the gap of minerals in different regions is mainly attribute to the parameters such as organic matter, pH, agrotype and botanical composition of pasture\textsuperscript{25}.

3.5 Fatty acid composition analysis

Fatty acid composition for Tibetan ghee of the different seven pasture sites is shown in Table A.2, the total SFAs was 40.99 g/100 g, which is substantially lower than that of African ghee (46.01%). Caprylic acid (C8) showed the significant regional variations ($p<0.05$), with averages of 0.64 g/100 g caprylic acid in Nagqu, 0.54 g/100 g in Ngari, 0.51...
g/100 g in Shigatse, 0.49 g/100 g in Sannan, 0.48 g/100 g in Qamdo, and the caprylic acid also varied significantly with the altitude ($p < 0.05$). However, the butyric acid ($C_{4:0}$) and capric acid ($C_{10:0}$) did not show significant difference ($p > 0.05$), with contents lower than that of Nepalese ghee ($C_{4:0}$ 1.67 g/100 g, $C_{8:0}$ 0.69 g/100 g, $C_{10:0}$ 2.41 g/100 g).\(^{23}\)

Myristic acid ($C_{14:0}$) ($3.92-9.85$ g/100 g) was lower than that of Indian ghee (11.60 g/100 g), Nepalese cheese (6.71%), cow milk (10.01 g/100 g), and yak milk (8.1 g/100 g).\(^{21}\) Furthermore, the myristic acid ($C_{14:0}$) showed the significant variation with the altitude ($p < 0.05$), calculating the averages of 3.94, 4.86, 4.15 g/100 g myristic acid ($C_{14:0}$) (respectively in the altitude of 4900 m, 4500 m and 3400 m) in TTG.

Palmitic ($22.19-28.04$ g/100 g) and oleic acid ($20.04-27.64$ g/100 g) are the dominant fatty acids in TTG. As shown in Table A. 2, palmitic acid ($C_{16:0}$) showed the significant regional variations ($p < 0.05$), the level of $C_{16:0}$ increased as the altitude increased, and the highest concentration ($27.67$ g/100 g) of that was found in Nagqu. Sawaya et al. also reported $C_{16:0}$ ($27.61–30.5$) and $C_{18:1}$ ($19.60–30.11$) are the predominant fatty acids in ghee and butter from goat’s and sheep’s milk.\(^{26}\) The content of palmitic acid ($C_{16:0}$) is in the same range of those reported for Nepalese ghee ($23.3$ g/100 g), French butter ($22.27-26.24$ g/100 g), and Holstein ghee ($25.25-25.43$ g/100 g);\(^{27}\) however, it is lower than that in traditional Tunisian butter (32.04%), Indian ghee (34.09 g/100 g), and Aba ghee (28.10%). Oleic acid ($C_{18:1}$) was detected in the range of $22.04-27.85$ g/100 g, which is slightly higher than that of Holstein ghee (16.98 g/100 g), goat milk

Fig. 4  Linear discriminant analysis based on the fatty acid composition of TTG. (a) Classification of fatty acid composition based on the altitude level. (b) Classification of fatty acid composition based on the region. (c) Principal component analysis loading plot based on the fatty acids in TTG.
Characteristics of Traditional Tibetan Ghee

(19.9 g/100 g), yak milk (20.4 g/100 g), and Eastern Anatolian ghee (15.22-24.02%). In Switzerland, Collomb et al. reported an average value of 0.7 g CLA/100 g milk fat\(^{(20)}\). Linoleic acid (C\(_{18:2}\)) n-6 amounts slightly varied depending on region from 0.29 to 1.41 g/100 g. These values are in the same range of the calculated content\(^{(20)}\), with the tiny content of linoleic acid (C\(_{18:2}\)), it shows the insignificant variations in altitude and region (p > 0.05).

Monosaturated fatty acids (MUFA\(\))\(s\) (oleic and erucylactic acid) account for 34.21 g/100 g. These values are higher than that of Indian ghee (27.32 g/100 g), Nepalese cheese (32.40 g/100 g), and traditional Tunisian butter (24.68%)\(^{(20)}\). Moreover, the health-affecting polyunsaturated fatty acids (PUFA\(\))\(s\) such as linoleic acid and eicosapentaenoic acid (EPA) is abundant, with 2.46 g/100 g\(^{(21)}\), which is slightly higher than that of Tunisian butter (2.41 g/100 g) and Buffalo milk (2.13 g/100 g); however, it is lower than that of the Holstein gheee (3.80 g/100 g), yak milk (4.91 g/100 g), and Indian ghee (2.36 g/100 g). The ratio of unsaturated to saturated (UFA/SFA) fatty acid is also an important criterion to evaluate the quality of TTG, which was approximately 0.83. The value of UFA/SFA is higher than that of Indian ghee (0.41), yak milk (0.78), cow milk (0.57), and Tunisian butter (0.38)\(^{(22)}\). The high level of UFA/SFA indicated the fatty acid composition in TTG is abundant and healthy, and the health-affecting fatty acids in TTG such as oleic acid (C\(_{18:1}\)), linoleic acid (C\(_{18:2}\)), CLAs (C\(_{18:2}\) cis 9, trans 11), arachidonic acid (C\(_{20:4}\)) and EPA are usually detected in ocean fish oil\(^{(21)}\). Moreover, the PUFA\(\)s in TTG (C\(_{18:2}\), CLAs, C\(_{20:5}\)) are in the range of 1.65–2.35 g/100 g. The effect of regional variations on the EPA (C\(_{20:5}\)) level showed significantly (p < 0.05), the averages of 0.47 g/100 g in Sannan, 0.39 g/100 g in Shigatse, 3.84 g/100 g in Nagqu\(^{(21)}\).

The TTG samples subjected to MANOVA analysis shows that the fatty acids in different regions showed the significant variation (p < 0.05), the results of the fatty acids contents based on the region are visualised in the LDA plot (Fig. 4b). The first discriminant function accounted for 78.1% of total variance and the second accounted for 21.9%, both of them account for 100% of total variance and separated into three distinct groups (D1 to D3, Fig. 4b). More specifically, the first discriminant function differentiates D2 (Lhasa, Sannan) from D3 (Ngari, Shigatse), the second discriminant function differentiates D1 (Qamdo, Nagqu) from D2 (Lhasa, Sannan). And the classification based on the regions in fatty acids mainly links to the local grass and fodder qualities, and all the factors such as regional weather, cow diet, breeding modes and bovine breed, may modulate the fatty acids contents of TTG.

Figure 4c shows that C\(_{18:1}\) and C\(_{16:0}\) are the dominant fatty acids in TTG, and the dominant fatty acids are confirmed the regional variations, with averages of 48.41 g/100 g ghee in D3 (Ngari, Shigatse), 50.21 g/100 g in D2 (Lhasa, Sannan), and 50.65 g/100 g in D1 (Qamdo, Nagqu), these results show that the fatty acids level are higher in eastern regions than in western area in Tibet. As reported, the geographical characteristics of the regions in Tibet (D1, D2, D3) is significantly different, the local characteristics of D3 (Ngari, Shigatse) are arid climate, high altitude level, precipitation deficit, and the fodder of yak is mainly composed of alpine meadow, upland meadow and brushwood. In D2 (Lhasa, Sannan) region, the regional weather belongs to the plateau temperate semi-arid monsoon climate, with strong solar radiation, long sunshine time, and there are abundant fodders such as shrubs and herbs, many of which are known for medicinal, aromatic, and nutritive properties. The regional climate features in D1 (Qamdo, Nagqu) region mainly shows the abundant sunshine, low humidity, and rainfall concentration, moreover, the area is covered with forest and grassland, many of which are rich in abundant PUFA\(\)s\(^{(21)}\). The regional effect on the grass pasture qualities, related to cow diet, ultimately influence the total fatty acid composition of TTG, moreover, the factors such as breeding methods, fodder quality and technology, cow breeds may affect fatty acids content of TTG.

4 Conclusion

TTG, as the dairy products is nourishing and attractive food for consumers, which actually contains some health-affecting fatty acids. It is important to update food data for physicochemical characteristics and a number of particular fatty acids such as CLAs and EPA.

TTG contains high proportion of dry matter, such as fat
(71.68%–93.39%), protein (0.51%–1.8%), and minerals (97.31–887.87 mg/L). Quality parameters such as AV and PV are within 0.02–1.30 mg/g and 0.07–5.93 meq/kg, respectively, the low PV indicates that the low quantities of FFAs are in TG. As detected by the FTIR spectra, high proportion (49.6%) of UFAs easily lead to generating rancid flavor. The minerals increased with altitude level higher significantly, and it also showed significant regional variations. Moreover, TTG is an excellent source of UFAs, especially medium and long chain fatty acids, and the content of fatty acids varied with altitude level and regions. The level of fatty acids in highlands is higher than in lowlands, however, the content of fatty acids in eastern regions is higher than western area in Tibet. These variations is mainly due to the differences in grass pasture qualities, regional weather, related to the breeding methods, grass and fodder qualities, yak diets, and so on.

Acknowledgement
The authors would like to thank the National Natural Science Foundation of China (NO.: 31671819) for the financial support.

Conflict of Interest
The authors have declared no conflicts of interest.

Supporting Information
This material is available free of charge via the Internet at http://dx.doi.org/jos.68.10.5650/jos.ess19031

References
9) Fındık, O.; Andiç, S. Some chemical and microbiological properties of the butter and the butter oil produced from the same raw material. LWT-Food Sci. Technol. 86, 233-239 (2017).
Characteristics of Traditional Tibetan Ghee


22) Wang, Z.; Zhang, Y.; Zhang, H.; Ding, M.; Lin, X. Major soil element (Ca, Mg, K, Na, Al, Fe) distribution along the Qinghai-Tibet Railway. in AGU Fall Meeting, Abstracts (2011).


