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Review

Tibetan Butter and Indian Ghee: A Review on Their Production and Adulteration

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Abstract: Tibetan butter and Indian ghee are both fat products derived from cow's milk or other dairy products that are rich in nutrients. Although both Tibetan butter and Indian ghee are primarily produced by filtering, heating, separating, cooling, and molding, there are differences in their production processes. Tibetan butter is produced in a process similar to that of butter, while Indian ghee is clarified butter obtained by further extraction based on the obtained butter. Both types of ghee are susceptible to adulteration; Indian ghee is primarily adulterated with vegetable oils, animal fats, and other fats or non-fats, while Tibetan butter is typically adulterated with animal body fat and non-fats, including mashed potatoes. There are numerous research reports on the detection techniques for adulteration in Indian ghee, while there are very few reports on the detection technology for adulteration of Tibetan butter. Studies have shown that techniques such as gas chromatography (GC), Fourier-transform infrared spectroscopy (FTIR), and electronic nose (E-nose), either individually or in combination, are efficient in distinguishing adulterated Indian ghee. These findings could serve as a reference for the detection of adulteration in Tibetan butter in the future.

Keywords: Tibetan butter; Indian ghee; adulteration; detection techniques

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1. Introduction

Tibetan butter and Indian ghee are both milk-fat products, which are collectively called ghee in this context. Ghee is an edible fat product derived from various types of milk, including fermented or unfermented cow, goat, buffalo, and yak milk [1,2]. Ghee is composed of 98.9% fat, regardless of the animal it comes from, and is notable for its high concentration of fatty acids, which has prompted the interest of nutritionists regarding the potential functional properties of these compounds [3]. Reports indicate that ghee contains short-chain fatty acids (SCFA), medium-chain fatty acids (MCFA), long-chain fatty acids (LCFA), and very-long-chain fatty acids (VLCFA) [3]. Among them, butyric acid (BA) is the only short-chain fatty acid, palmitic acid (PA) is the principal saturated fatty acid, and oleic acid (OA) is the primary unsaturated fatty acid [4–6]. Ghee also includes additional fatty acids, such as linoleic acid (LA), α-linolenic acid (LNA), and arachidonic acid (AA) [7]. PA and OA regulate blood lipid levels and effectively reduce the occurrence of hypercholesterolemia and cardiovascular disease [4–6]. LA has been demonstrated to have anti-inflammatory qualities and it may be used to treat skin inflammation and reduce blood pressure [8–10]. Conjugated linoleic acid (CLA) formed from LA has been shown to possess physiological functions, including prevention of atherosclerosis and promotion of growth and development [11–13]. LNA can facilitate the production of physiologically active eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) within the body, of which EPA is a widely used agent for the prevention and treatment of cardiovascular and

cerebrovascular diseases in middle-aged and elderly individuals [14,15], and DHA plays an important role in promoting growth and development [16], whereas AA possesses anti-inflammatory and cardiovascular-disease-preventive characteristics.

In general, the richness of fatty acids in ghee provides not only a source of energy but also many health benefits through its physiological functions, making ghee and related products popular among Indian and Tibetan consumers. In India, ghee consumption is particularly prevalent [17]; approximately 27.5% of the total milk production in India is used for ghee production [18], and the per capita ghee consumption can reach 15.6 kg per year [19]. The Indian ghee market is projected to reach Indian Rupee (INR) 3203 billion by 2023 [20]. In China, ghee is produced in many regions, including Tibet, Qinghai, Inner Mongolia, Sichuan, and Yunnan [7], among which Tibetan butter is renowned, which is made from yak milk and pien niu (offspring of a bull and a female yak) milk as the main raw material, and typically, 100 kg of yak milk is used to yield approximately 4–5 kg of it. Tibetan butter is a favored food and the primary source of energy and fat for Tibetan residents, and as an important part of their diet, more than 25,000 tons of Tibetan butter are consumed annually in Tibet.

2. The Production Process of Tibetan Butter and Indian Ghee

The article here only describes the differences between Tibetan butter and Indian ghee in terms of raw materials and production processes. In terms of raw milk, the sources of raw milk for Tibetan butter are usually yaks, dzos, and cows [21], while Indian butter has a wider range of sources of raw milk, including yak milk, buffalo milk, goat milk or mixed milk [22]. In terms of production processes, the steps of mechanized production of Tibetan butter are shown in Figure 1a. In detail, it involves the following steps [21].

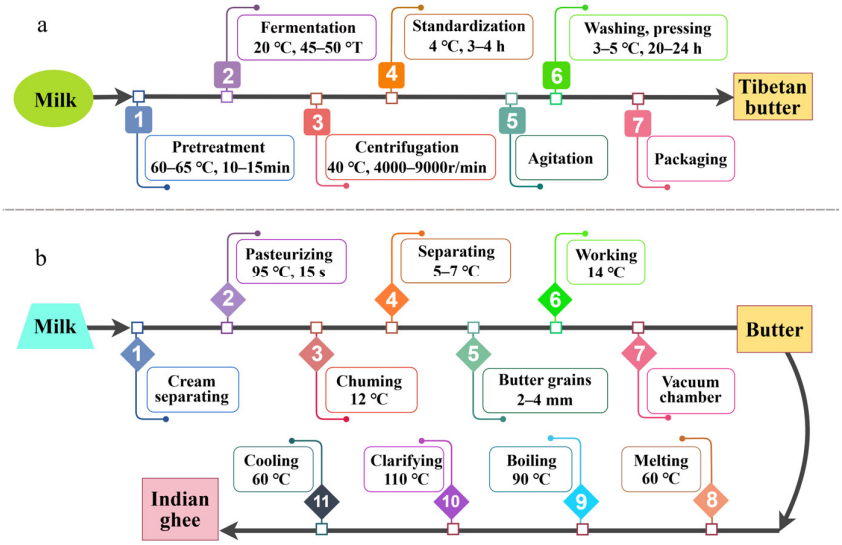


Figure 1. The processing methods of ghee. (**a**) Flow diagram for manufacturing Tibetan butter; (**b**) flow diagram for manufacturing Indian ghee.

(1) Pretreatment of raw materials: The yak milk that has been collected undergoes pasteurization (at a temperature of 60–65 °C for a duration of 10–15 min). It is then filtered and immediately cooled to a temperature of 2–4 °C for storage, and within 24 h, the butter is extracted from it.

(2) Fermentation of yak milk: Prior to extracting butter from yak milk, it is necessary to subject it to fermentation treatment. This involves inoculating the milk with a fermentation agent at a rate of 1.0% and maintaining a fermentation temperature of 20 °C. Fermentation can be halted when the acidity of the non-fat portion of yak milk reaches a range of 45–50 °T.

(3) Milk fat separation by centrifugation: The fermented yak milk is heated to a temperature of 40 °C and thereafter introduced into a centrifuge. The yak milk is centrifuged at a speed ranging from 4000 to 9000 revolutions per minute, resulting in the separation of yak milk cream and skimmed yak milk. The Pearson approach can be employed to standardize the yak milk cream in this process.
(4) Standardization and physical maturation: The cream is subjected to standardization and placed in a controlled environment with a temperature of 4 °C for a period of physical maturation, typically lasting 3–4 h.
(5) Agitation: Transfer the fully matured cream into a blender for the purpose of stirring. If solid butter particles, resembling soybeans in size, are observed in the cream, the process can be halted.
(6) Washing and pressing: Rinse the butter particles with distilled water at a temperature of 3–5 °C, and thereafter apply pressure to them at the same temperature for a duration of 20–24 h, ensuring that the moisture content does not exceed 16%.
(7) Packaging: The compressed butter should be promptly packaged using materials that are resistant to oil and water and do not allow light or air to pass through.

It can be seen that the processing of Tibetan butter is comparable to regular butter production. However, Indian ghee is derived from butter using a similar method as Tibetan butter, followed by further heating to eliminate water content, which is essentially an anhydrous milk fat. Briefly, in the mechanized production of Indian ghee, the process involves obtaining butter, which is then melted at a temperature of 60 °C. Then, the water content is gradually removed in a steam pressure boiler operating at 90 °C. Finally, the ghee is obtained when the temperature reaches 110 °C [22] (Figure 1b).

There are few variations in the production methods of Tibetan butter and Indian ghee, and they have parallels in terms of their primary constituents and nutritional content; some methods can also be shared in determining the nutrient content of ghee and identifying its adulteration status.

3. Adulteration of Ghee and Its Detection Techniques

3.1. Overview of Adulteration in Ghee

In the context of intense market competition, some manufacturers, driven by the desire to boost sales and profits, resort to the addition of cheaper different oils to ghee to reduce the overall cost of the product. Consider Indian ghee as an illustration, as reported in the literature of the last decade, the main adulterants found in Indian ghee include vegetable oils like sunflower, soybean, peanut, coconut, cotton seed, and palm oils; animal fats and oils such as caprine body fat, tallow, goat body fat, and lard; other fats and oils like margarine and mineral oils; and non-fats and oils like starch and potatoes (Tables 1 and 2). In China, Tibetan butter is priced at approximately CNY 150 per kilogram, a significantly higher cost compared to conventional vegetable oil and animal fat; the substantial difference in price has led to the former being adulterated with the less expensive latter and various alternatives. Animal body fat is commonly used as an adulterant in Tibetan butter, including the body fat of pigs, cows, and sheep. This is along with mashed potatoes, which we also frequently found adulterated in our investigation. Adulteration of these substances in ghee would not only affect the nutritional value of ghee but may even constitute a major food safety hazard.

It is necessary to manage and control the adulteration in butter to safeguard the rights and health of consumers. Thus, various analytical techniques have been used to identify vegetable oils, animal body fats, and other adulterants in pure or mixed ghee samples. However, there are numerous studies on the detection of adulteration in Indian butter, while relatively few studies have been reported on Tibetan butter because of the volume of production. There is only the Tibet Autonomous Region and Qinghai Province that have established local and group standards for ghee production and processing, respectively [54–56]. Therefore, this article summarizes various methods for detecting adulteration in Indian ghee, which can serve as a reference for detecting adulteration in Tibetan butter.

Table 1. Adulterants in ghee and their detection methods (adulterants from animal fats).

Source Material	Adulterant	Detection Method	LOD	Reference
Pig	Lard	Low-resolution GC	0.063	[23]
	Pig body fat	ATR-FTIR	0.03	[24]
	Lard	Portable NIR spectrometer	0.05	[25]
	Lard	Gas–liquid chromatography	-	
Cow	Tallow	Physical constants	-	[17]
	Beef tallow	Low-resolution GC	0.02	[23]
	Cow body fat	Electronic nose	0.1	[26]
	Tallow	Novel high-performance TLC	<20%	[27]
	Tallow	Derivative spectrophotometry	0.1	[28]
Goat	Goat body fat	ATR-FTIR	0.01	[29]
	Caprine body fat	DSC	0.05	[30]
	Goat body fat	Complete liquefication time test coupled with solvent fractionation technique	0.1	[31]
	Goat body fat	Species-specific simplex polymer chain reaction	0.1	[32]
Vanaspati or margarine	Vanaspati	Flash GC electronic nose	0.1	[33]
	Margarine	Electronic nose	0.1	[34]
	Vanaspati	Image analysis	0.05	[35,36]
	Margarine	Gas–liquid chromatography	-	
Others	Cow milk	Fluorescence spectroscopy	0.1	[37]
	Cow ghee into buffalo ghee	Raman spectroscopy	0.1	[38]
	Cattle–yak ghee	Raman spectroscopy	0.05	[39]
	Foreign fats in desserts prepared using ghee	Low-resolution GC	-	[40]

Table 2. Adulterants in ghee and their detection methods (adulterants from vegetable oils).

Source Material	Adulterant	Detection Method	LOD	Reference
Soybean	Soybean oil	Physical constants	-	[17]
	Soybean oil	Flash GC electronic nose	0.1	[41]
	Soybean oil	FT-MIR and FT-NIR spectroscopies	0.1	[42]
	Soybean oil	RP-TLC	0.01	[43]
	Soybean oil	Standardized RP-TLC	0.01	[44]
	Soybean oil	Barcode genotyping assays	0.05	[28]
	Soybean oil	Normal-phase TLC	0.05	[45]
	Refined soybean oil	RP-HPLC	0.01	[46]
Sunflower	Sunflower oil	Electronic nose	0.1	[26]
	Sunflower oil	RP-TLC	0.01	[43]
	Sunflower oil	Standardized RP-TLC	0.01	[44]
	Refined sunflower oil	RP-HPLC	0.02	[46]
	Sunflower oil	Barcode genotyping assays	0.05	[28]
	Sunflower oil	DPPH impregnated paper based color sensor disc	0.01	[47]
Groundnut	Groundnut oil	RP-TLC	0.01	[43]
	Groundnut oil	Standardized RP-TLC	0.01	[44]
	Groundnut oil	RP-HPLC	0.02	[46]
	Groundnut oil	Complete liquefication time test coupled with solvent fractionation technique	0.1	[31]

Table 2. *Cont.*

Source Material	Adulterant	Detection Method	LOD	Reference
Coconut	Coconut oil	Physical constants	-	[17]
	Coconut oil	Low-resolution GC	0.02	[23]
	Coconut oil	ATR-FTIR	0.02	[48]
	Coconut oil	RP-HPLC	0.05	[46]
Vegetable	Vegetable oil	Portable NIR spectrometer	0.03	[25]
	Vegetable oils	FT-MIR	-	[49]
	Vegetable fat	Image analysis	0.1	[50]
	Vegetable fat	Low-resolution GC	0.05	[23]
	Hydrogenated vegetable oil	Physical constants	-	[17]
Others	Palm oil	DPPH impregnated paper based color sensor disc	0.025	[47]
	Cotton seed oil	GC-MS and HPLC	0.1	[18]
	Corn	Barcode genotyping assays	0.05	[51]
	Rapeseed	Barcode genotyping assays	0.05	[51]
	Banaspati	Fluorescence spectroscopy	-	[52]
	Highly manipulated fat	GC of triglycerides	0.005	[53]

3.2. Detection Methods of Adulterants in Ghee

The detection of Indian ghee adulteration is primarily based on differences in the components of pure ghee and adulterants. The detection techniques include physical constant detection, chromatographic methods for ghee detection, some emerging techniques, spectral analysis methods for ghee detection, and others (Figure 2, Tables 1 and 2). The main techniques of each method are described next.

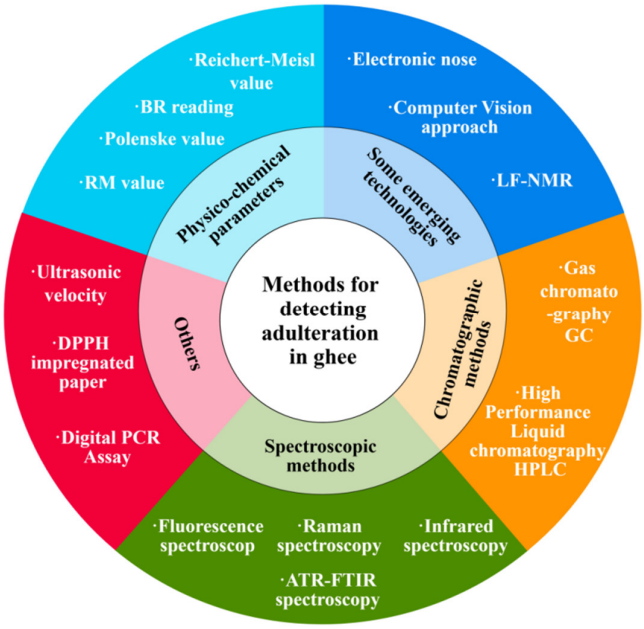


Figure 2. Different techniques for detecting ghee adulterants.

3.2.1. Physico-Chemical Parameter Detection

Several physical constants associated with oils and fats can identify ghee [17]. Fatty acids can be measured using the Reichert Meissl (RM), Kirschner, acid, and Polenske values, and they are commonly used to evaluate the quality of oils and fats. The RM value was defined as the volume of normal alkali solution required to neutralize water-soluble fatty acids extracted from 5 g of milk fat, expressed in units of 1/10 mL. The Kirschner value was determined by adding silver sulfate powder (0.5 g) to the neutralized

solution obtained using the RM procedure. The acid value is defined as the amount of potassium hydroxide (KOH) needed to neutralize the unbound fatty acids present in 1 g of fat. This value functions as an indicator of the quantity of unbound fatty acids contained in the fat samples. Similarly, the Polenske value was used to measure the amount of volatile fatty acids in oils and fats. It determined the quantity of NaOH needed to neutralize the volatile and water-insoluble fatty acids present in the samples. Besides the indicators used to assess fatty acid content, iodine and butyrorefractometer (BR) values can also serve as indicators of adulteration in ghee. Iodine can indicate the degree of unsaturation of fats and oils, whereas a BR reflects the refractive index of the sample. Nevertheless, other studies have demonstrated the limited effectiveness of using physical constants to detect adulteration [18]. Consequently, it is imperative to refine the physical constant detection method, enhance its detection precision, or implement a more efficacious detection approach.

3.2.2. Chromatographic Methods for Ghee Detection

Gas chromatography (GC): GC is the method specified by the International Organization for Standardization (ISO) for testing the purity of milk and milk products [57]; this method uses the distinction between the triglyceride profiles of milk fat and other fats to ascertain the adulteration status of milk fat samples. According to Kala et al., the use of gas chromatography may identify vegetable oils and animal body fats in ghee or shortening-based foods by analyzing fatty acids, triacylglycerols, and sterols [40]. In a study by Kala et al., low-resolution GC was used to analyze coconut oil, beef tallow, vegetable fat, and lard in ghee [23]. The resulting detection limits were 2%, 2%, 5%, and 6.3%, respectively. Roy et al. used a flash GC electronic nose coupled with multivariate chemometrics to detect adulterants in cow ghee [33,41]. Their findings indicate this method is an efficient and convenient technique for confirming adulteration. However, owing to the complexity and multiplicity of ghee adulterants, a single GC is increasingly unable to meet the determination requirements. Consequently, the concurrent application of GC and other analytical techniques is likely to emerge as a dominant approach for the detection of ghee adulteration. To obtain more accurate results, coupled analytical techniques, such as gas chromatography–liquid chromatography (GC-LC), gas chromatography–mass spectrometry (GC-MS), and liquid chromatography–mass spectrometry (LC-MS), have been used for other edible oils' detection.

High-performance liquid chromatography (HPLC): HPLC is a commonly employed method for the separation and analysis of substances that possess high boiling temperatures, large molecular sizes, significant polarity, and poor thermal stability. This method has the advantages of high efficiency and high sensitivity, and it can also determine multiple components of a substance. The current applications of this technology are well established and widely used. Atbhaiya et al. used gas chromatography–mass spectrometry (GC-MS) and HPLC to investigate adulteration in ghee [18]. The results showed these analytical techniques can be used to distinguish between ghee produced in cottonseed areas and ghee that had been adulterated with cottonseed oil. Reverse-phase-HPLC (RP-HPLC) is a commonly used method. RP-HPLC is a separation system comprising a nonpolar stationary phase and a polar mobile phase, which can be used to analyze organic substances soluble in polar or weakly polar solvents. The method's advantages of rapidity, economy, and high reliability have led to its widespread use for the quantification of natural products in food, identification of additive residues, and analysis of substance interactions [58–60]. In a separate study, sterol profiling using RP-HPLC was proposed as a more effective method than RP-TLC for the detection of plant oils in ghee [46]. However, issues such as limited portability and long-term consumption must be resolved.

3.2.3. Spectral Analysis Methods for Ghee Detection

Fourier-transform infrared spectroscopy (FTIR): FTIR is an analytical technique used to obtain infrared spectra by measuring interferograms and applying Fourier transforms to

them. This method can identify functional groups, determine chemical structures, observe the course of chemical reactions, and analyze the purity of substances. The primary components of fats and oils are triglycerides, and the quantities of methylene and carbon-carbon double bonds can serve as proxies for the types and concentrations of fatty acids present in different fats and oils. Infrared spectroscopy can reflect this variability, enabling the detection of adulteration in fats and oils. Attenuated total reflectance Fourier-transform infrared spectroscopy (ATR-FTIR) [24,29,48], Fourier-transform near-infrared spectroscopy (FT-NIR) [42], and Fourier-transform mid-infrared spectroscopy (FT-MIR) are three frequently employed techniques for identifying adulteration in ghee [42,49]. All these methods have the advantages of being environmentally friendly, accurate, easy to operate, nondestructive, and inexpensive, as well as requiring minimal sample preparation and allowing for rapid data collection.

Fluorescence spectroscopy (FS): FS is an analysis method based on the molecular fluorescence properties of a sample. This method is nondestructive, efficient, and sensitive, and it does not require sample pretreatment. It is widely used for the detection of food adulteration, including that of olive oil, honey, and milk [61–63]. Furthermore, statistical analysis of fluorescence spectra has demonstrated the successful adulteration of banaspati and cow milk in ghee [37,52]. These findings indicate that, although fluorescence spectroscopy may be susceptible to certain limitations, such as the presence of fewer chemicals that can cause fluorescence and mutual elemental interference, the use of portable fluorescence sensors with chemometric tools can be a viable approach for the detection of ghee adulteration in everyday settings, as long as chemometrics continue to evolve.

Raman spectroscopy (RS): RS is a nondestructive analytical technique that relies on the principle of light scattering. It has been proven to be useful for the characterization of fats in milk and the adulteration of butter components, as evidenced by previous studies [64,65]. The absorption intensity at specific wavelengths in Raman spectroscopy can be utilized to qualitatively and quantitatively analyze edible oils and fats, owing to the correspondence between different chemical bonding vibrations in oil molecules and fixed wavelengths. Ahmad [38] quantified the content of β-carotenoids, free cholesterol, vitamin D, and CLA using different Raman spectral bands (1006, 1156, 1520, and 1080 cm^{-1}) and developed a partial least squares regression model to predict the adulteration of buffalo ghee with cow ghee. Among the identified compounds, β-carotene was employed as a biomarker to distinguish between the two types of ghee.

3.2.4. Other Methods

Electronic-nose technology (E-nose): E-nose is a class of devices that are often combined with sensor arrays to detect and distinguish odors accurately in complex samples. Besides chemical sensors, piezoelectric and electrochemical sensors have been developed and applied to electronic-nose technology. Because it is reliable, efficient, rapid, and sensitive, it is commonly used for monitoring food freshness, biological contamination, and food quality [66–68]. Some studies have used principal component analysis and artificial neural networks to analyze data collected using electronic-nose technology, which can identify adulterated ghee with an accuracy of over 80% [26,34].

Low-field nuclear magnetic resonance (LF-NMR): LF-NMR is a method of analyzing the structure and properties of a substance by using the phenomenon of NMR. The principle of LF-NMR is to stimulate the nuclei of atoms in a substance with an applied magnetic field and then to detect the signals generated by the nuclei, obtaining information on the structure and properties of the substance. LF-NMR is used to assess the quality of foodstuffs [69,70], with the transverse and longitudinal relaxation times and their respective proton densities measured [71]. Compared to traditional analytical methods and detection techniques, LF-NMR is more convenient, and its use for food adulteration detection allows for a more diverse range of analyses. Although there are no reports on LF-NMR for the detection of ghee adulteration, this method has been widely used for the detection of

adulterants in a variety of edible oils, including coconut, olive, and peanut oils [72–74]. This technique shows promise and can be quickly applied in ghee analysis methodologies.

Besides these methods, researchers have employed additional techniques to identify adulterants in ghee. For example, Upadhyay et al. conducted a study to assess the effectiveness of a solvent fractionation technique in lowering the detection limit of ghee samples that contained peanut oil and goat body fat [31]. The results demonstrate that this strategy can significantly improve the sensitivity of the detection procedure, offering a simple and cost-effective alternative to traditional methods. In a separate study, Uncu et al. demonstrated the efficacy of two PCR capillary electrophoresis methods for the detection of adulterated vegetable oil in ghee [51]. The first method targeted the plastid *trnL* (UAA) intron, whereas the second method employed a nested format to target the intron's inner P6 loop. The intron enhanced species recognition, whereas the P6 ring improved the detection sensitivity. De and Jirankalgikar used derivative spectrophotometry, a rapid, sensitive, and economical method, to identify the presence of tallow in cow ghee as an adulterant [28]. The study demonstrated that the value of OD_{297} nm/OD_{238} nm decreased consistently with an increasing proportion of tallow, indicating its potential for the quantitative estimation of adulterants. In addition, given that butyric acid is only present in milk fat, the lack of butyric acid in adulterant oils and fats has been the basis of numerous analytical methods for detecting ghee adulteration [75].

Despite the existence of several detection methods, the conventional evaluation of the physical and chemical properties of fats and oils is insufficient for accurately identifying them. Consequently, the development of nondestructive, effective, universal, accurate, and reliable testing methods represents a prospective trend. GC is the most effective method for detecting the adulteration of ghee, owing to its simplicity and sensitivity. Consequently, the ISO designated GC as the standard method for testing the purity of milk and its products.

3.3. Detection Methods of Adulterants in Tibetan Butter

There are currently fewer reports on techniques for detecting adulteration in Tibetan butter. In the limited reports available, Liang et al. used high-resolution Raman spectroscopy in combination with multivariate data processing to identify cattle–yak ghee from yak ghee samples. In the study, the Raman spectra of ghee were analyzed to explore the band differences of 1007, 1156, and 1520 cm^{-1}, which are assigned to β-carotene, as well as the band at 1656 cm^{-1}, which is assigned to CLA. The PLS-DA model, using the entire spectral range, successfully detected yak ghee samples that were contaminated with cattle–yak ghee at a mass fraction above 5% [39].

While there is a limited amount of information available on the detection of adulteration, some reports on the study of Tibetan butter's quality could serve as a useful point of reference for detecting adulteration. Marquardt et al. analyzed the fatty acid (FA) profile of ghee produced from milk of cattle–yak hybrids. It was found that ghee made from hybrids' milk had more α-linolenic and linoleic acids than yak ghee [76]. Yak ghee, on the other hand, had more saturated FAs and eicosapentaenoic, docosapentaenoic, and docosahexaenoic acids [76]. Yang et al. analyzed the lipid profiles in yak ghee samples collected from different elevations, finding that yak ghee contained a high amount of neutralizing glycerophospholipids and various functional lipids, including sphingolipids and 21 newly discovered functional lipids [77]. These results may inform us to find specific substances in Tibetan butter or further develop appropriate adulteration detection methods based on them.

4. Discussion

In this review, many methods have been reported to be effective in detecting adulterants in ghee. But some of the methods have different recognition rates for different adulterants in ghee. For example, according to Kala et al., the detection level of low-resolution GC was found to be 6.3% in case of lard addition in the ghee, but only 2% in case of beef tallow in the ghee [23]. Others, such as Upadhyay et al., have reported that when ATR-FTIR was used for detecting pig body fat in pure ghee, the adulteration could be de-

tected at a level of 3% [24], while the adulteration could be detected at a level of 10% when RS was used to detect cow ghee in buffalo ghee, according to Ahmad et al. [38]. Thus, it will be necessary to optimize existing detection methods, further improve their sensitivity and specificity, and make them more suitable for the detection of ghee adulteration, especially investigating the potential of integrating diverse technologies to offset the limitations of the individual detection methods.

For example, gas chromatography–ion mobility spectroscopy (GC-IMS) is an emerging method for detecting adulteration in edible oils. This method is based on the separation of volatile organic compounds in samples by GC, ionization, and their movement in an IMS. Adulteration of safflower seed oil was first identified by Han et al. using GC-IMS and the electronic-nose method [78]. The results demonstrated that GC-IMS can distinguish safflower seed oil from other types of oils. By establishing ion mobility spectra and fingerprints, Wu et al. performed qualitative and quantitative tests on the volatile compounds present in Ganoderma lucidum spore oil in order to assess the level of adulteration [79]. The findings indicated that GC-IMS is a valuable analytical method for assessing the quality of Ganoderma lucidum spore oil and that its ability to identify adulteration can be as low as 5%. Compared with single-instrument analysis, coupled analytical techniques offer enhanced accuracy, speed, separation capabilities, and quantitative analysis. Consequently, the potential of using this method for the detection of ghee adulteration should also be considered. Furthermore, it is possible to innovate and promote new technology.

But in any case, it is ultimately necessary for the relevant production areas to implement appropriate food safety regulatory measures. Examples of such measures include strengthening the construction of regulatory institutions and mechanisms, stepping up efforts to combat adulteration and other egregious acts, and accelerating the establishment or improvement of hygiene standards and common convenient testing methods for ghee. By implementing these measures, it is possible to ensure the quality and safety of ghee at the source and effectively safeguard human health.

5. Conclusions

This review describes the similarities and differences in the production processes of Tibetan butter and Indian ghee, with a focus on the adulteration of ghee products. In terms of production process, the process of Tibetan butter is similar to that of regular butter, whereas Indian ghee needs to be obtained by continued heating on top of the butter obtained, which is also called clarified ghee because more water is removed at a temperature of 110 °C. In terms of adulteration, it describes the types of adulterants found in ghee, including vegetable oils, animal fats, and other fats or non-fats, with the types of adulteration found in Indian ghee being significantly more complex than those found in Tibetan butter. In addition, it provides a detailed overview of the current detection methods used to identify adulterants in Indian ghee. These methods include physico-chemical parameter detection; chromatographic methods; spectral analysis methods; and some emerging techniques, such as GC, E-nose, and FTIR, which have been proven efficacy in identifying adulteration. However, this review covers fewer detection techniques for adulterants in Tibetan butter, as less research has been reported in this area. The article suggests that we can draw inspiration from the methods of detecting adulteration in Indian ghee. For example, utilizing techniques such as GC, E-nose, and GC-IMS, either individually or in combination, to detect adulterants in Tibetan butter, due to their proven efficacy in identifying adulteration in Indian ghee or their superior ability to detect adulteration in other types of fats and oils.

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