Aroma Sensory Properties of Gouda Cheeses Based on Young Chinese Consumers’ Preference

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ABSTRACT

The objective of this study was to examine the aroma profiles of 12 Gouda cheeses sold in China and determine which aromas were preferred by young Chinese consumers (n = 110). The consumers selected 11 descriptors of the aromas of the Gouda cheeses in a Check-All-That-Apply (CATA) questionnaire. These 11 descriptors were used by a panel of experts for sensory analysis to perform a Quantitative Descriptive Analysis (QDA) of the cheeses. A principal component analysis of the data from the QDA revealed that the characteristic aromas of the young Gouda cheeses, medium-aged Gouda cheeses and aged Gouda cheeses were “milky” and “whey”; “creamy”; and “sour,” “rancid,” “nutty,” etc., respectively. The results of a penalty analysis combined with the CATA results and the preference scores showed that the 3 groups of young Chinese consumers (those who often ate cheese, occasionally ate cheese, and never ate cheese) preferred the Gouda cheeses with “milky” or “creamy” aromas and did not like those with “sour” or “rancid” aromas. Occasional cheese eaters comprised the majority of the young Chinese consumers, and they were more tolerant of the Gouda cheeses with “whey” and “sulfury” aromas than those who often ate cheese and those who never ate cheese. In addition, there was a positive correlation between the consumers’ preferences for the aromas of the Gouda cheeses and their willingness to pay for the cheeses. Overall, the results of this study should help promote the development of Gouda cheeses and associated products that meet the preferences of young Chinese consumers.

Keywords: Gouda cheese, young Chinese consumers’ preference, sensory evaluation, aroma characteristics

INTRODUCTION

Gouda cheese is a representative round-holed cheese and one of the most well-known cheeses in the world (Garcia-Cano, Rocha-Mendoza, Kosmerl, & Jimenez-Flores, 2020). It originated in the Netherlands and is also produced in Germany, Poland and other European countries. It is usually made from pasteurized milk; has a rich, unique flavor and smooth texture and comprises 50–60% of global cheese consumption (Sulieman, Ohag, Hassan, Abdelmageed, & Veetil, 2018). It also typically has a yellow skin, a flat cylindrical shape, and a mild aroma. It can be an excellent raw material for manufacturing processed cheese and spreadable cheese, and thus, it is very popular with consumers globally (Indumathi, Kaushik, Arora, & Wadhwa, 2015).

The aroma characteristics of cheese have a substantial influence on consumers’ acceptance or preferences for the cheese. Sensory evaluations of cheese by consumers are effective for assessing and quantifying the aroma characteristics of cheese, and determining which aromas are preferred by consumers (Sidel & Stone, 1993). Moreover, sensory evaluations of a food by consumers and by professional sensory evaluators afford a comprehensive understanding of the food’s aroma characteristics and which aromas are preferred by consumers of the food (Morais Ferreira, Azevedo, Luccas, & Bolini, 2017). The Check-All-That-Apply method (CATA) is a rapid sensory analysis method that uses consumer evaluators instead of professional sensory evaluators (Alexi, Nanou, Lazo, Guerrero, Grigorakis, & Byrne, 2018). The CATA method typically employs a 9-point hedonic scale that is used by consumers to quantify their level of preference for a food sample, and this information is employed to enhance the development or marketing of a food (Silva, Duarte, Mendes, Pinto, Barroso, Ganhao, et al., 2020). This method has been successfully used in the study of acid-cured cheese, commercial creamy cheese, and other cheese products (Foguel, Neves Rodrigues Ract, & Claro da Silva, 2021; Tian, Sun, Yu, Ai, & Chen, 2020).
(QDA) is a form of descriptive analysis whereby trained evaluators quantitatively analyze and describe all of the properties of a food (Lawless & Heymann, 2010). This analysis method was recently used to determine the aroma characteristics of a traditional Chinese cheese and quantify its aroma intensity (Tian, Xu, Chen, & Yu, 2019). Therefore, the abovementioned methods are effective for examining and quantifying the aroma and other sensory characteristics of cheeses and consumer preferences for such characteristics.

Gouda cheeses of different maturities, i.e., ages, often exhibit different aroma characteristics (Wang, Cui, Chen, & Zhang, 2011). Therefore, the cheese purchased by consumers depends on their own aroma preferences and cooking methods (Van Hoorde, Verstraete, Vandamme, & Huys, 2008). Research on consumer preferences for Gouda cheese has mainly been conducted in Western countries. For example, a team at North Carolina State University studied United States’ consumers’ preferences for Gouda cheese and found that most consumers preferred mild flavored Goudas and some consumers preferred aged Gouda cheese (Jo, Benoist, Amerally, & Drake, 2018). However as Chinese culture, diets and living habits are distinct from those of the West, Chinese consumers’ preferences for Gouda cheese aromas may be different from those of Western consumers (Zhang, Guo, Zhao, Sun, Zeng, Lu, et al., 2011). Improvements in the living standards of Chinese consumers and increased awareness of the need for a healthy diet has led to year-on-year increases in cheese consumption in China, such that the Chinese cheese market has entered a golden period of development (Wu, Lu, Xu, Lv, Hu, He, et al., 2018). Young Gouda cheese is characterized by a mild aroma, and is ready-to-eat and easily processable into cheese snacks; thus, it is well suited for meeting the market demand in China. Therefore, Gouda cheese has broad market potential in China. In addition, young people have strong willingness to consume. They are more likely to develop new taste habits and are the main drivers of cheese consumption in China (Lowe-Wincentsen, 2016; Zhang, et al., 2011). Accordingly, there is a need to study the aroma profiles of Gouda cheese, and determine what Gouda cheese aromas are preferred by young Chinese consumers, as this will support the further introduction of Gouda cheese into China and its development in China.

Therefore, this study aimed to (1) use a CATA questionnaire completed by young Chinese consumers and a QDA performed by a panel of professional sensory evaluators to evaluate the aroma characteristics of Gouda cheeses; (2) determine the Gouda cheese aromas preferred by young Chinese consumers based on their completed CATA questionnaires; (3) group the young Chinese consumers according to their frequency of cheese consumption and then perform a penalty analysis to understand the between-group differences in preferences for Gouda cheese aromas and (4) perform correlation analysis to determine the relationship between young Chinese consumers’ preference of Gouda cheese and willingness to pay for the Gouda cheese. The results of this study may serve as a reference to support the introduction and promotion of Gouda cheese in China, and the future development of cheeses that better meet the needs of the Chinese market than the cheeses currently available in China.

MATERIALS AND METHODS

Cheese samples

Samples of 12 different Gouda cheeses in separate packages that had been imported from their country of manufacture were purchased from an imported food store in Shanghai, China. These samples are classic Gouda cheese and can be easily bought by consumers in the Chinese market. The package size of each Gouda cheese was 2 to 4 kg. Each cheese was obtained in multiple lots. Different lots of cheese were chopped and mixed for subsequent sensory evaluation. The detailed information of these samples is shown in Table 1. The maturity of cheese is marked on the product packaging. The samples were labeled “G1” to “G12” and were classified by their age into 3 categories: young cheeses (G1–G4), medium-aged cheese (G5–G8) and mature cheeses (G9–G12). The samples were transferred from the store to the laboratory via guaranteed cold-chain transportation and stored in a thermostatic refrigerator at –20°C. Before sensory evaluation by the young Chinese consumers and the expert panel of professional sensory evaluators, the samples were placed in a 4°C refrigerator for 12 h and subsequently at room temperature (25°C), until their temperature reached room temperature.

Sensory evaluation

The sensory evaluation involved a CATA-questionnaire-based assessment performed by a panel of consumers and a QDA performed by a panel of experts.

Participants

The panel of consumers consisted of 110 consumers aged 18–44 (62 women and 48 men), who were recruited from their hometowns in various provinces in China and lived temporarily in Shanghai, China. The panel comprised students, teachers, employees and oth-
The panel of experts consisted of 20 professional sensory evaluators (10 men and 10 women) who each had more than 200 h of sensory evaluation experience of cheese. They had previously received formal sensory evaluation training and passed the assessment. Before sensory evaluation, experts were specially trained for Gouda cheese to assess aroma properties accurately and stably. The training lasted at least 5 d (2 h/day). During the course of the training, the trainees are first introduced to the descriptive terms of aroma. They were instructed on how to smell the cheese samples to ensure consistency. Second, some Gouda samples with relatively small differences were prepared, and trainees were asked to distinguish and describe these samples. Finally, the trainees were asked to smell the reference substances of different aromas, and repeated exercises and evaluations were performed until all the panellists could correctly identify 100% of the standard reference substances. Before the sensory evaluations, we explained the experimental method and the composition of the samples to the participants, obtained their written consent to participate and informed them that they could stop participating at any time. None of the participants had colds or diseases that affected their sense of smell, such as olfactory damage or respiratory tract infections, and none of them were using drugs that affect taste perception. The appropriate protocols for protecting the rights and privacy of all of the participants were utilized during the execution of the research. This study had no coercion to participation, and its requirements and risks were fully disclosed to the participants. The research content was explained by research ethics board of Shanghai Institute of Technology (No. SIT-2023-LL03).

**Consumer assessment**

A 5-g subsample of cheese was placed in a brown glass (50 mL) that was labeled with a random 3-digit code. Cheese was presented at 25°C. This process was repeated for each of the 12 samples. Consumer assessment was conducted within 2 d, with each consumer assessing 6 cheese samples per day. Moreover, consumers were asked to rest for 5 min at the evaluation interval of every 2 samples, during which normal saline was provided to consumers for nasal irrigation to avoid olfactory fatigue. The 12 glasses were then individually to the consumer panel with complete randomized block design order to avoid the influence of carry-over and position (Ares, Dauber, Fernández, Giménez, & Varela, 2014). First, the consumers were asked to complete a cheese-consumption frequency questionnaire, in which they chose one of the following 3 options: “I never eat cheese,” “I eat cheese occasionally” or “I often eat cheese.” Next, the consumers were asked to rate how much they liked each subsample’s aroma on a 9-point hedonic scale (where 1 = “I disliked the aroma very much,” 5 = “I neither liked nor disliked the aroma” and 9 = “I liked the aroma very much”) (García-Gómez, Romero-Rodríguez, Vázquez-Ódériz, Muñoz-Ferreiro, & Vázquez, 2019). Subsequently, they smelled each subsample and then indicated on a CATA questionnaire containing 21 descriptive terms related to the aroma characteristics of cheese the term that they thought best described the aroma profile of the subsample. The terms used in the CATA questionnaire were “nutty,” “phenolic,” “salivary,” “sour,” “yeasty,” “peppery,” “milky,” “musty,” “cocoa,” “toasted,” “caramelly,” “brothy,” “whey,” “rancid,” “fruity,” “creamy,” “floral,” “sulfury,” “honey,” “oniony” and “alcohol.” These terms were based on those reported in the literature (Jo, Beenoist, Ameerally, & Drake, 2018; Los, Simões, Benvenuti, Zielinski, Alberti, & Nogueira, 2021; Van Leuven, Van Caelenberg, & Dirinck, 2008) and those identified in a preliminary sensory study. In the preliminary sen-

### Table 1. Information on the 12 Gouda cheese samples

<table>
<thead>
<tr>
<th>Label</th>
<th>Name</th>
<th>Country of Manufacture</th>
<th>Maturity</th>
<th>Protein (%)</th>
<th>Fat (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>G1</td>
<td>Sterilgarda</td>
<td>Netherlands</td>
<td>Young</td>
<td>22.8</td>
<td>29.9</td>
</tr>
<tr>
<td>G2</td>
<td>Wartburg</td>
<td>Netherlands</td>
<td>Young</td>
<td>25.0</td>
<td>24.0</td>
</tr>
<tr>
<td>G3</td>
<td>President</td>
<td>Netherlands</td>
<td>Young</td>
<td>22.0</td>
<td>26.0</td>
</tr>
<tr>
<td>G4</td>
<td>Kerrygold</td>
<td>Ireland</td>
<td>Young</td>
<td>24.0</td>
<td>32.0</td>
</tr>
<tr>
<td>G5</td>
<td>Spomlek</td>
<td>Poland</td>
<td>Medium</td>
<td>27.0</td>
<td>28.0</td>
</tr>
<tr>
<td>G6</td>
<td>Spomlek</td>
<td>Poland</td>
<td>Medium</td>
<td>28.0</td>
<td>28.0</td>
</tr>
<tr>
<td>G7</td>
<td>Spomlek</td>
<td>Poland</td>
<td>Medium</td>
<td>27.0</td>
<td>30.0</td>
</tr>
<tr>
<td>G8</td>
<td>Emborg</td>
<td>Germany</td>
<td>Medium</td>
<td>25.0</td>
<td>29.0</td>
</tr>
<tr>
<td>G9</td>
<td>Best-long</td>
<td>Netherlands</td>
<td>Aged</td>
<td>24.1</td>
<td>33.7</td>
</tr>
<tr>
<td>G10</td>
<td>Beemster</td>
<td>Netherlands</td>
<td>Aged</td>
<td>27.7</td>
<td>35.0</td>
</tr>
<tr>
<td>G11</td>
<td>Sterilgarda</td>
<td>Netherlands</td>
<td>Aged</td>
<td>26.1</td>
<td>33.2</td>
</tr>
<tr>
<td>G12</td>
<td>Best-long</td>
<td>Netherlands</td>
<td>Aged</td>
<td>29.0</td>
<td>35.0</td>
</tr>
</tbody>
</table>
sory study, the expert panel discussed and screened the terms. Consumers who participated in the test stated that these terms are easy to understand. Terms that were selected in the CATA questionnaire were recorded if their selection rate was greater than 50% and were not recorded if their selection rate was less than 50%. The ratio of the number of times a descriptive term was selected to the maximum possible number of times it could have been selected was defined as its $F$ value.

Survey of consumers’ willingness to pay for the cheeses was subsequent conducted. The consumers’ willingness to pay for the 12 Gouda cheeses was assessed using a consumer willingness questionnaire that they completed after smelling each subsample. At the top of the questionnaire, the average prices of the 12 Gouda cheeses were listed, and at the bottom of the questionnaire, the following question was printed: “Would you be willing to pay the stated price for the cheese you have just smelled?”. This question was answered by the consumers by ticking one of the following 3 options: “Yes,” “Maybe” or “No.” After the consumers had completed all the questionnaire, they were each given a gift (e.g., a voucher) to compensate them for their time.

QDA

Eleven sensory descriptive terms were selected for the QDA based on the answers provided by the consumer panel in the CATA questionnaires. The definitions and references for these terms are given in Table 2. The mean values and ANOVA from the descriptive sensory data are shown in Table 3. The QDA was completed by the expert panel. First, a 5-g subsample of Gouda cheese was placed in a 50-mL lidded soufflé cup labeled with a 3-digit random code. This process was repeated for each of the 12 samples. Next, we present the samples in the order of randomized complete block design to avoid legacy effects as much as possible (Ares, Dauber, Fernández, Giménez, & Varela, 2014). The expert panel evaluated the intensity of the aromas of the subsamples on a 10-point unstructured intensity scale, which was represented by “not intense” on the left side and “highly intense” on the right side. Sensory evaluation and consumer testing software (APPsense 9.5; Yinghuali Technology Co., Ltd., Beijing, China) was used for data collection. Subsamples of all 12 Gouda cheese samples were evaluated during the session, and the panelists were asked to take a 2-min break between each subsample evaluation. The evaluations were conducted in a sensory laboratory without stray light, noise or other interference, in accordance with GB/T 29605–2013 and ISO 4121–2003 guidelines. The evaluation is repeated in triplicate.

Statistical analysis

Data collection and statistical analyses were performed using APPsense (version 9.5) and SPSS (version 21.0; SPSS Inc., Chicago, IL, USA) software. Descriptive analysis results and consumer preference data were analyzed using ANOVA and Fisher’s least significant difference test, with $P < 0.05$ considered as indicating a significant difference. The data-processing software Canoco (Canoco for Windows 5.0; Microcomputer Power, Ithaca, NY, USA) was used for principal component analysis, and the results were applied to descriptive analysis, which was used to determine the differences between the samples. The consumption intention data are presented in the form of the percentage of “Yes” answers for the questionnaire. Spearman’s correlation method was used to study the correlation between the consumers’ preference scores and consumption intention scores. Origin Pro (version 2021; OriginLab, Northampton, MA, USA) software was used to draw the figures.

RESULTS AND DISCUSSION

CATA results and determination of the frequency of the use of descriptive terms

Figure 1 depicts the $F$ values of the 21 descriptive terms for the aroma of Gouda cheeses in the consumer panel’s completed CATA questionnaires. Eleven descriptive terms had $F$ values greater than 50%; these were as follows (in descending order of $F$-value): “milky,” “creamy,” “sour,” “rancid,” “toasted,” “fruity,” “nutty,” “sulphury,” “whey,” “cocoa” and “brothy.” The $F$ values of “milky” and “cream” were 79.8% and 74.6%, indicating that most of the consumers believed that the majority of the 12 Gouda cheese samples had “milky” or “creamy” aromas. This is consistent with the fact that “milky” and “creamy” have often been reported in studies on Gouda cheese aromas (Jo, Benoist, Ameerally, & Varela, 2008). In addition, the $F$ values of “fruity,” “toasted,” “sulphury,” “sour,” “rancid” and “nutty” were also high (60–70%). In contrast, the $F$ values of “peppery” and “oniony” were low (5.5% and 6.3%, respectively); thus, they were regarded as unsuitable for describing the aromas of the 12 Gouda cheese samples and were not used in the QDA. Then the definitions of these 11 descriptive terms and examples of substances, materials, or foods whose aromas they describe are listed in Table 3.
Results of QDA

The results of the expert panel’s QDA of the aromas of the subsamples of the 12 Gouda cheese samples are shown in Figure 2. As in the results of the CATA questionnaire, the “milky” and “creamy” aromas were regarded as more intense than the other aromas, and were regarded as significantly more intense than the other aromas in subsamples of G1, G2, G3 and G4 ($P < 0.05$). In a previous study, we showed that “milky” and “creamy” aromas were more intense than other aromas in young Gouda cheeses and these aromas correlated with aroma compounds, such as diacetyl and acetoin (Chen, Tian, Yu, Yuan, Wang, Xu, et al., 2022). The intensity of “fruity” aromas was significantly higher in the subsamples of G9, G11 and G12 than in the other subsamples ($P < 0.05$). Such “fruity” aromas are characteristics of cheeses with a high degree of ripening and are largely due to the accumulation of esters, such as ethyl caproate and ethyl butyrate (Wang, Yang, Cao, Wang, & Liu, 2021). The proportions of these esters in Gouda cheese increase as the cheese matures (Alewijn, Sliwinski, & Wouters, 2005), which is consistent with the fact that G9, G11 and G12 were aged Gouda cheeses. The “sulfury” aroma had the lowest intensity of the 11 aromas across the subsamples, and it was slightly more intense in the G6–G12 subsamples than in the other subsamples. Recent studies have found that Gouda, Edam, Emmental, and Cheddar cheeses contain sulfurous compounds and have similar “sulfury” aromas (El-Shamy & Farag, 2022; Wang, Yang, Xu, Wang, Zhang, & Li, et al., 2021). The “nutty” aroma had a significantly higher intensity in subsamples G9–G12 than in subsamples G1–G4. This finding is similar to our previous findings in a study of cheddar cheese (Chen Chen, Zhou, Yu, Yuan, & Tian, 2021). The “nut-

Table 2. Selected descriptive terms used to characterize the aromas of 12 Gouda cheeses

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
<th>Chemical/food with aroma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milky</td>
<td>Aromatics associated with cooked milk</td>
<td>Skim milk heated to 85°C and held at this temperature for 30 min</td>
</tr>
<tr>
<td>Creamy</td>
<td>Aromatics associated with natural, fresh cream</td>
<td>Fresh unsalted and unsweetened free natural cream</td>
</tr>
<tr>
<td>Brothy</td>
<td>Aromatics associated with cooked meat or vegetable soups</td>
<td>Canned potatoes, Wheeler low-sodium beef soup (frozen, 20 mg/L)</td>
</tr>
<tr>
<td>Fruity</td>
<td>Aromatics associated with fruit</td>
<td>Fresh pineapple</td>
</tr>
<tr>
<td>Fruity</td>
<td>Aromatics associated with fruits that can be cooked with some starches and sugars</td>
<td>Ethyl hexanoate (20 mg/L)</td>
</tr>
<tr>
<td>Toasted</td>
<td>Aromatics associated with grains that are heated sufficiently to cook some starches and sugars</td>
<td>Toasted sliced bread</td>
</tr>
<tr>
<td>Sulphury</td>
<td>Aromatics associated with sulphorous compounds</td>
<td>Boiled mashed egg</td>
</tr>
<tr>
<td>Sour</td>
<td>Aromatics associated with acidic compounds</td>
<td>Hydrogen sulfide bubbled through water; struck match</td>
</tr>
<tr>
<td>Rancid</td>
<td>Aromatics associated with short-chain fatty acids</td>
<td>Acetic acid solution (100 mg/L)</td>
</tr>
<tr>
<td>Nutty</td>
<td>Aromatics associated with nuts</td>
<td>Lightly roasted salt-free nut wheat germ</td>
</tr>
<tr>
<td>Nutty</td>
<td>Aromatics associated with nuts</td>
<td>Salt-free wheat flakes</td>
</tr>
<tr>
<td>Whey</td>
<td>Aromatics associated with Gouda cheese whey</td>
<td>Roasted peanut oil extract</td>
</tr>
<tr>
<td>Cocoa</td>
<td>Aromatics associated with cocoa</td>
<td>Fresh Gouda whey</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fresh cocoa butter</td>
</tr>
</tbody>
</table>

*The terms listed refer to the existing literature (Drake, McIngvale, Gerard, Cadwallader, & Civille, 2001; Talavera-Bianchi & Chambers, 2008).
ty” aroma is largely due to branched aldehydes, such as 2-methylbutanal and 3-methylbutanal, which increase in concentration with the maturity of the cheese (Chen et al., 2020, 2021). Therefore, the accumulation of nutty-flavored compounds as Gouda cheese matures accounts for the intense “nutty” aroma of aged Gouda cheeses. The “whey” aroma was more intense in the G1–G4 subsamples than in the other subsamples, due to the small amount of fresh whey protein remaining in young cheeses (G1–G4). As cheese matures, many compounds in whey are decomposed by microorganisms, which reduces the intensity of the “whey” aroma (Jo, Benoist, Ameerally, & Drake, 2018).

In addition, more than 82% of the attributes between cheeses are statistically different, so it is suitable for PCA biplot. The QDA data were subjected to principal component (PC) analysis to further clarify the characteristic aromas of the 12 Gouda cheeses (Figure 3). The cumulative variance contribution rate of PC1 and PC2 was 92.17%, indicating that PC1 and PC2 fully reflected the comprehensive information of the samples (Cozzolino, Power, & Chapman, 2019). The 3 groups of cheese—G1–G4, G5–G8 and G9–G12—were clearly distinguished from each other in PC1 and PC2. This indicates that Gouda cheeses of different maturities had significantly different aroma characteristics. G1–G4 had characteristic “milky” and “whey” aromas, whereas G5–G8 had a characteristic “creamy” aroma. This is consistent with the results of a recent study, which found that low- or medium-maturity Gouda cheeses have characteristic “milky,” “whey” and “creamy” aromas (Jo, Benoist, Ameerally, & Drake, 2018). However, compared with the characteristic aromas of the young and medium-aged Gouda cheeses (G1–G4 and G5–G8), those of the aged Gouda cheeses (G9–G12) comprised more aromas, i.e., the following 8 aromas: “sour,” “rancid,” “nutty,” “brothy,” “fruity,” “toasted,” “sulfury” and “cocoa.” This is consistent with a previous study, which showed that, compared with less mature cheddar cheeses, more mature cheddar cheeses had a more complex aroma profile (Wang, Yang, Xu, Wang, Zhang, & Li, et al., 2021).

### Results of consumer preference assessment

The consumers’ preference for the 12 Gouda cheeses is shown in Figure 4. Their preference score was highest for G1 (6.82 points), followed by G4, and the preference scores for these 2 cheeses were significantly higher than those for other samples (P < 0.05). The preference scores for the young Gouda cheeses (G1–G4) were slightly higher than those for the medium-aged Gouda cheeses and significantly higher than those for the aged Gouda cheeses (P < 0.05). G10 had the lowest prefer-

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**Figure 1.** Frequency of use of each descriptive term for the aroma of Gouda cheeses in completed CATA questionnaires. The F value represents the ratio of the number of times a descriptive term was selected to the maximum possible number of times it could have been selected.
ence score (4.18), which was less than half of the highest possible score. The accumulation of odorous substances and the complexity of the aroma during ripening may be the main reasons for the unpopularity of this aged Gouda cheese (Alewijn, Sliwinski, & Wouters, 2005).

Figure 4 shows consumers’ preferences for the different Gouda cheeses, but there are some limitations to these data. For example, it is unknown which aromas of Gouda cheese were favored by consumers and which were not favored. Thus, the CATA questionnaire data and consumer preference data were combined and subjected to a penalty analysis. The results are shown in Figure 5, where the mean impact of descriptive terms for aromas on the consumers’ preference for a sample is depicted on the y-axis. A descriptive term in the positive quadrant had a positive impact on the consumers’ preference for a sample, and a descriptive term in the negative quadrant had a negative impact on the consumers’ preference for a sample. The x-coordinate reflects the frequency with which a descriptive term was used to describe the aromas of all of the samples. “Milky,” “creamy,” “toasted,” “fruity,” “nutty,” and “cocoa” had a positive impact on consumer preference and thus, indicated why the consumers preferred these samples. “Milky” and “creamy” were the most frequently selected and had a large average influence, as shown by their position near the upper-right corner of the axis, far from the other aromas. This shows that “milky” and “creamy” aromas had a greater positive impact on these consumers’ preferences than other preferred aromas, i.e., these consumers preferred Gouda cheese with “milky” and “creamy” aromas. This is similar to the results of a previous study on Chinese consumers’ preference for other cheese aromas (Ma, Gong, Wu, & Liu, 2006). “Rancid,” “sour,” “sulfury,” “whey” and “brothy” were in the negative quadrant, indicating that these aromas had a negative effect on consumers’ preference for the samples. Moreover, “sour” and “rancid” are close to the lower-right corner, indicating that they are the main reasons why these consumers did not like the samples with these 2 aromas. Interestingly, studies in the United States and Ireland found that consumers do not reject cheeses with “sour” attributes (Jo, Benoist, Ameerally, & Drake, 2018; Murray & Delahunty, 2000). Although Chinese and Western eating habits are different (Ojeda, Etaio, Valentin, Dacremont, Zannoni, Tupasela, et al., 2021), some similarities existed in consumers’ preferences for Gouda cheese.

The penalty analysis of aroma preferences of consumers who never eat cheese, occasionally eat cheese and often eat cheese is shown in Figure 6. Different groups had different preferences for aromas, which is consistent with the findings of other recent studies (e.g., Los, Simões, Benvenutti, Zielinski, Alberti, & Nogueira, 2021). This indicates that the frequency of eating cheese affects consumers’ preferences for Gouda cheese aromas.

The 3 groups of consumers had almost the same low preference for the “rancid” aroma and thus, did not like this aroma. The group of consumers who never ate cheese had a particular preference for “milky” and “creamy” aromas, and represented 19.1% of the consumers in the study. The group of consumers who often ate cheese had a greater tolerance for the “sour” aroma than the other 2 groups and accounted for 14.5% of the consumers. Thus, consumers with a higher frequency of

![Aroma-intensity bubble diagram of the 12 Gouda cheeses, where the diameter of a bubble indicates the intensity of the aroma.](image-url)
daily consumption of cheese preferred “fruity” “brothy” and “nutty” aromas. Most of the consumers only occasionally ate cheese (66.4%) and their level of preferences for most aromas were between those who regularly ate cheese and those who never ate cheese. Interestingly, the consumers who occasionally ate cheese were more tolerant of “whey” and “sulfury” aromas than consumers who often ate cheese or never ate cheese. These results are consistent with previous study on cheese and consumers (Zhang, Guo, Zhao, Sun, Zeng, Lu, et al., 2011).

**Correlation between consumer aroma preferences and willingness to pay**

To determine whether the preferences of the consumers for Gouda cheese aromas was related to their willingness to pay for these cheeses, a Spearman’s correlation test was performed on the 2 sets of data. The results showed that there is a significant positive correlation between the consumers’ preferences for the cheese aromas and their willingness to pay for these cheeses ($P < 0.01$). Furthermore, their preference and willingness to pay were linearly correlated ($R^2 = 0.9638$). Thus, the consumers’ preference for Gouda cheese aromas affected their willingness to pay for the Gouda cheeses. Similarly, a consumer study on vegetable protein cheeses found that when participants gave a neutral or positive preference greater than or equal to 4 for these cheeses, there was a significant positive correlation between their preference scores for these cheeses and their willingness to pay for these cheeses (Saint-Eve, Irlinger, Pénicaud, Souchon, & Marette, 2021).

**CONCLUSION**

Eleven descriptive terms for aromas were screened in a CATA questionnaire by young Chinese consumers to describe the aroma characteristics of 12 Gouda cheeses and were used by an expert panel of professional sensory evaluators to perform a QDA of these cheeses. The terms were “milky,” “creamy,” “brothy,” “fruity,” “toasted,” “sulfury,” “sour,” “rancid,” “nutty,” “whey” and “cocoa.” The characteristic aromas of young Gouda cheeses were found to be “milky” and “whey,” the characteristic aroma of medium Gouda was found to be “creamy” and the characteristic aromas of aged Gouda were “fruity,” “sour” and “rancid.” Gouda cheeses with “sour” and “rancid” aromas were not preferred, whereas those with “milky” and “creamy” aromas were pre-

**Figure 3.** Principal component analysis of the aroma intensity of 12 Gouda cheeses.
ferred. The number of consumers who only occasionally ate cheese comprised the majority of the consumers in this study and they were more tolerant of “whey” and “sulfury” aromas than the consumers who ate cheese more often. Consumers who more frequently ate cheese had greater tolerance for “sour” and “brothy” aromas. In addition, all of the consumers preferred “milky” and “creamy” aromas, irrespective of their frequency of cheese consumption. There was a positive correlation between the consumers’ aroma preferences for the 12 Gouda cheeses and their willingness to pay for these cheeses. Overall, the findings of this study will inform the importation of original and processed Gouda cheeses into China and their development in China. In our future study, more sensory evaluators will be recruited, and retronasal assessment and taste perception of cheese will be explored, such that the preferences of Chinese consumers for Gouda cheeses can be met.

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Conflicts of interest The authors declare that they have no known competing financial interests or personal relationships that may have influenced the work reported in this paper.

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Figure 4. Consumer preference scores for 12 Gouda cheeses. Different letters in the figure indicate significant differences between samples (P < 0.05).
Figure 5. Mean impact of aromas of the Gouda cheeses on young Chinese consumers' preference for these cheeses. The y-axis reflects the mean impact of aroma descriptors on consumer sample preference. The x-axis reflects the frequency with which a descriptive term was used to describe the aromas of all of the samples.
Figure 6. Penalty analysis of the Gouda aroma preferences of the 3 groups of young Chinese consumers.

Chen et al.: Aroma evaluation of Gouda cheese

Cocoa
Whey
Nutty
Rancid
Sour
Sulphury
Toasted
Fruity
Brothy
Creamy
Milky

Frequency of use of descriptive term (%)

Often eat cheese
Eat cheese occasionally
Never eat cheese

Mean impact

-2.5  -2.0  -1.5  -1.0  -0.5  0.0  0.5  1.0  1.5


