Evidence of *terroir* in milk sourcing and its influence on Cheddar cheese

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ABSTRACT

The concept of local food is rapidly gaining importance within the United States. The foundation of local food is *terroir*, which links a food to its production environment. The purpose of this study was to investigate evidence of *terroir* in milk sourcing and its influence on Cheddar cheese flavor. Specifically, the study was designed to assess if consumers could differentiate between Cheddar cheeses made with milk from different dairy farms. Milk from 5 locations, including single dairy farms and commingled sites, was collected from around the state of Oregon. Using raw and pasteurized counterparts of the milk, Cheddar cheese was made and aged. At 5 and 9 mo into aging, Cheddar cheese consumers were asked to group the samples based on perceived similarity/dissimilarity of cheese flavor. Grouping data were subjected to multidimensional scaling and subsequent cluster analysis. Results at 5 mo into aging revealed that cheeses made by milk originating from different farms (80 km apart) within the same region were perceived as different, whereas cheeses made with milk from neighboring farms (5 km apart) were grouped together, irrespective of heat treatment (i.e., raw vs. pasteurized). Cheeses made with commingled milk from different regions grouped together. At 9 mo of aging, in contrast, a clear separation of perceived flavor was present between the pasteurized and raw cheese samples, whereas the effect of milk sourcing was less pronounced. These data suggest that the geographical location of the milk source has an effect on the flavor of Cheddar cheese, but that the practices of milk commingling and heat treatment likely reduce the effect of geographical location, particularly as cheese ages.

Key words: Cheddar, flavor, pasteurization, commingling

INTRODUCTION

Terroir is a French term referring to the conditions in which a food is grown or produced that give the food its unique sensory characteristics (Barham, 2003). The term is also defined as “local area with homogeneous environment and production systems” (Brunschwig et al., 1999). The concept of *terroir* has served as the basis of the European Union’s geographic indications, known as protected designation of origin (PDO), which promote and protect the names of agricultural products (e.g., Champagne, Camembert). The term *terroir* also has a cultural dimension that ties a product to local community and lifestyle through traditional production and local knowhow.

The effect of *terroir* on differences in flavor has mostly been studied in wine. The *vini-terroir* relates these differences as a direct result of the natural environment of the vine (Moran, 2006). The natural environment, specifically the macro-, meso-, and micro-climate, geology and pedology, water availability, native microbial populations, and harvest time all independently have the ability to affect the final sensory characteristics of wine (Jackson and Lombard, 1993; Van Leeuwen and Seguin, 2006; Gilbert et al., 2014). In addition to wine, other plant-based products, such as coffee and olive oil, have demonstrated sensory characteristics linked to the territory of production. Costa Rican coffee beans have been shown to produce beverages with different aroma, acidity, and body based upon the slope exposure and altitude of the growing region (Avelino et al., 2005). Similarly, olives of the same cultivar, but grown in different regions, produce oils with particular volatile compounds and sensory profiles (Kalua et al., 2007).

Dairy products, such as cheese, have a more complex relationship to the area of production. Just like wine, soil and climactic conditions serve as the base of *terroir* by selecting for certain pasture and forage characteristics. It is known that when different plants are included in the cow’s diet, they influence the chemical composition of and thereby sensory qualities of milk (Carpino et al., 2004a; Coulon et al., 2004; Martin et al., 2005; Rapisarda et al., 2013). Further, it has also been

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shown that variations of homogenous edaphic regions correspond to the variations in sensory characteristics of alpine cheeses (Monnet et al., 2000; Povolio et al., 2013). The dairy farm environment also contributes to the native microflora of the milk (Kagkli et al., 2007) that ultimately affects the cheese (Pintado et al., 2008).

In addition to the natural environment, the animal presents an additional intermediary step between the raw commodity and the final product. The breed of the animal is an important aspect of the final sensory characteristics of the cheese. Different bovine breeds can produce different protein and fat levels, which influence the final sensorial characteristics of the cheese. Furthermore, a genetic variation within a single breed can cause differences of specific milk proteins resulting in modifications in sensory profile of cheese (Coulon et al., 2004). Therefore, popular PDO cheeses, such as Parmigiano-Reggiano and Comté, have strict local foraging and animal criteria, thus serving as the first direct link to area of production (Bertoni et al., 2001).

In addition to how the milk is produced, treatments applied to milk may also affect the expression of *terroir* in cheese. Milk is pasteurized to kill pathogens and extend shelf-life by significantly reducing overall levels of spoilage bacteria. Unfortunately, thermal treatment also affects other potentially beneficial native flavor-producing microflora, the nonstarter lactic acid bacteria (Shakeel-Ur-Rehman et al., 2000). Thus, cheeses made using raw milk have a more heterogeneous microbial population and are often more strongly flavored than their pasteurized counterparts (McSweeney et al., 1993; Muir et al., 1995). These adventitious microbial populations have been shown to vary between raw milk sources and manufacturing sites and thereby may play an important role in *terroir* in cheese (Berthier et al., 2001; Crow et al., 2001; Poznanski et al., 2004).

Most *terroir* research pertaining to cheese is focused on European cheese made from raw milk, where specific appellations are already in place. In contrast, research dealing with the *terroir* effect in popular American-style cheese is lacking. Several studies have investigated flavor differences in Cheddar cheese from various US regions and consumer perception of those cheese samples (Drake et al., 2005, 2008, 2009). However, these studies were not meant to investigate *terroir*, but rather to provide information on the diversity of commercial US Cheddar cheese. Therefore, these studies did not attempt to control for milk source, make procedures, milk pretreatment, manufacturing environment, and age of cheese, which would all be confounding factors in the study of *terroir*. It could be argued that each dairy processing plant constitutes its own *terroir* due to resident nonstarter lactic acid

bacteria, processing capabilities, and equipment, all of which would significantly affect cheese characteristics. Conducting a milk sourcing study will therefore require that either the processing plant is kept constant or the effect of the processing plant is determined separately. For the purpose of this study, the processing plant was kept constant.

The potential expression of *terroir* of Cheddar cheese in a localized US landscape was explored in this study. More specifically, the study was designed to assess if consumers could differentiate between Cheddar cheeses made with milk from different dairy farms. In addition, we explored if consumers' ability to differentiate cheeses was affected by commingling, geographical distance between farms, pasteurization of cheese milk, and aging of the cheese. Milk was collected from distinct regions as well as localized farms around Oregon, and manufactured into raw and pasteurized Cheddar cheese. The cheese samples were tested at 5 and 9 mo into aging. Although there are no legal definitions for designations (Drake et al., 2009), 5- and 9-mo-old cheeses are considered as "medium" and "sharp" Cheddar, respectively.

MATERIALS AND METHODS

Milk Collection

Milk was collected from 5 locations around the state of Oregon (Figure 1) over the course of early fall (October 2–24). Locations were strategically selected based upon individual ecoregions, or microclimates, delimited based upon geology, physical geography, vegetation, climate, soils, land use, and hydrology (Thorson et al., 2003). Milk was received from individual dairies in the Willamette Valley (**F1**, **F2**, and **F3**), and commingled from 2 additional regions: Coastal Range (**R1**), and Columbia Plateau (**R2**). All 5 locations had predominantly Jersey herds on pasture-based diets. The F1 and F2 dairies with pure Jersey herds are separated by 5 km, with the F3 dairy (86% Jersey herd) located about 80 km away. Milk was collected at 2 different times from the F3 location (F3.1 and F3.2) as a blind duplication to validate consistent cheese making and testing procedure. Milk from the R1 and R2 locations came from independent regions, and each sample was commingled from 2 to 3 local dairy farms.

All raw milk was collected directly from the bulk tank (F1, F2, and F3) or tanker truck (R1 and R2) after being stored on site for less than 48 h. The milk was kept below 4.4°C during transportation to the Arbuthnot Dairy Center (Oregon State University, Corvallis, OR) and stored at 2.2°C for no longer than 24 h before manufacture.

Figure 1. Ecoregions of Oregon based on geographic information system data (adapted from Thorson et al., 2003). Milk was collected from the Willamette Valley (F1, F2, and F3), Coastal Range (R1), and the Colombia Plateau (R2) ecoregions. Milk from F3 was collected at 2 separate occasions. Map source: US Environmental Protection Agency, Washington, DC.

Cheese Manufacture

Cheddar cheeses were manufactured at the Arbuthnot Dairy Center following the process and formulation adapted from the Western Dairy Center (Rogers et al., 2009). Raw milk was first analyzed for composition using a LactiCheck ultrasonic milk analyzer (Page & Pederson International Ltd., Hopkinton, MA) and standardized to a protein:fat ratio of 0.83. Milk from each location was made into separate raw and pasteurized milk Cheddar cheese batches. Batch pasteurization of the milk was set at 63°C for 30 min (FDA, 2013) in a 120-L vat (C. van t'Riet Dairy Technology, DuBois, PA). Pressed cheeses were vacuum-sealed in 75- μ m vacuum pouches (UltraSource LLC, Kansas City, MO) and stored at 5°C with rotation once a week to mitigate any temperature gradient within the storage chamber.

Proximate Analysis and Safety

Cheese composition was determined after 2 mo of storage for uniformity. Cross-sectional 100-g plugs were removed from each cheese and finely shredded. Shredded samples were tested using a NIR FoodScan

Dairy Analyzer (Foss, Hillerød, Denmark) for moisture, fat, protein, and salt. The pH was measured using an Orion Star A211 pH Benchtop Meter (Thermo Fisher Scientific Inc., Waltham, MA). To ensure safety for consumption, milk samples were tested for antibiotic residues (Charm Sciences Inc., Lawrence, MA) before cheese making. Cheeses were also tested by a third party laboratory (BioLogix Resources LLC, Portland, OR) for the presence of potential pathogens (*Listeria*, *Escherichia coli*, *Salmonella*) before sensory testing.

Sensory Study

Pilot Test. Prior to the formal sensory study, a pilot test was performed by 6 sensory and dairy professionals (3 male, 3 female) who were blind to the cheese samples. They performed the same sorting task described below to see whether the experimental design was adequate. The panel agreed that the total number of samples was manageable for a sorting task, but that the performance would be increased if the task was split into 2 separate sessions. They also agreed that replicate samples were similar in quality.

Subjects. Subjects were recruited from the Oregon State University campus and surrounding area. Testing at 5 mo consisted of 22 subjects (17 female and 5 male) between 18 and 60 yr of age. Testing at 9 mo included 21 subjects (16 female and 5 male) between 18 and 60 yr of age. Sorting tasks have shown to produce reliable results with about 20 consumers (Lim and Green, 2007; Nestrud and Lawless, 2010; Santosa et al., 2010). Subject inclusion criteria were individuals who (1) consume Cheddar cheese at least 2 to 4 times per week, (2) consume at least a 1/4 lb (115 g) of Cheddar cheese per week, (3) were willing to consume cheese made from raw milk. Respondents who met all of the listed criteria were invited to participate in the study. Participants were asked to refrain from eating at least 1 h before sensory testing. The Oregon State University Institutional Review Board approved the use of human subjects within the experimental protocol. Participants gave informed consent and were compensated for their participation with a \$10 gift certificate for each session.

Cheeses. A total of 12 cheeses were used for sensory testing: each sampling location (F1, F2, F3, R1, and R2), including the 2 replicated samples from F3, were represented by a pasteurized and raw sample. The blind duplication of the F3 location served to assess the stability of the sorting procedure (Lawless and Heymann, 1999) in addition to validating consistent cheese making and testing procedure. The external 2 cm of the cheese wheel was cut away to eliminate flavors associated with packaging. Dual cubes (2 cm³) of each cheddar cheese sample were placed in 60-mL clear plastic portion cups with lids (Solo Foodservice, Lake Forest, IL), labeled with 3-digit random codes. The cheeses were allowed to warm to room temperature for 30 min before being served.

Sorting Task. Sorting tasks were employed to assess perceptual differences between cheese samples at 2 different aging points: 5 and 9 mo into aging. The experiment was conducted over 2 sessions on 2 consecutive days to mitigate panelists' fatigue. Panelists were given a tray with all 12 cheese samples (6 raw, 6 pasteurized) in a random order along with a sheet for recoding responses during each test session. Panelists were presented with a fresh tray of cheese samples for each session. Note that we employed a sorting task instead of other techniques such as similarity ratings to produce a projective map because similarity judging methods have limitations of fatigue, adaptation, and carry-over effects (Lawless et al., 1995).

In the first session, panelists were instructed to taste all the cheeses in any order and as many times as they wished, and sort them into groups based upon similar flavor qualities. No limits were placed on the number of groups or the number of cheeses in each group, except

that the panelists were asked to form a minimum of 2 groups. Paper and pencil were provided for panelists to make notes. Once the panelists finished the initial sorting, they recoded their responses by writing down the 3-digit codes for each group of samples in separate columns with notes regarding flavor characteristics of each group.

In the second session, panelists were asked to complete the task by making changes or confirming their groupings. Panelists were provided with their groupings from the previous session as a reference.

Data Analysis

Individual panelist groupings were entered into an aggregate group similarity matrix based on how many times each sample was grouped together. The data were analyzed using nonmetric multidimensional scaling (MDS) in 2 and 3 dimensions. Subsequent cluster analysis using the MDS output (i.e., distance matrix) was further performed. All data analysis was performed by Statistica 12 (StatSoft Inc., Tulsa, OK).

RESULTS

Proximate Analysis

Results from the proximate analysis at 2 mo are presented in Table 1. Each cheese was within the legal Cheddar cheese requirements of no less than 50% milk fat by weight of the solids and no more than 39% moisture content by weight [CFR 21 (133.113b); CFR, 2011; FDA, 2013]. No significant differences were observed among cheeses with averages for fat, moisture, protein, salt, and pH at 34.5%, 34.0%, 25.6%, 1.6%, and 5.3, respectively. All cheeses included in the sensory testing had no detected antibiotic residues or pathogens.

Testing at 5 Months

Consumer Sorting. Subjects formed 3 to 8 groups (mean: 4.82, SD: 1.22). The stress values for the 2-D and 3-D MDS solutions were 0.12 and 0.08, respectively. The 3-D MDS solution was chosen due to the lower stress value, representing a better fitting model describing the relationships in the data. The final 3-D configuration is shown in Figure 2.

The blind-duplicate F3 samples, both raw (F3.1.R and F3.2.R) and pasteurized (F3.1.P and F3.2.P), were plotted close together in the spatial map, indicating that they were grouped frequently and perceived as quite similar. The pairing of these duplicates validates the consistency of the procedure (Lawless et al., 1995). Likewise, both the raw (R1.R and R2.R) and pasteur-

Figure 2. Three-dimensional multidimensional scaling (MDS) spatial mapping of cheeses at 5 mo into aging. Cheeses were made with milk collected from the Willamette Valley (F1, F2, and F3), Coastal Range (R1), and the Colombia Plateau (R2) ecoregions. Milk from F3 was collected on 2 separate occasions. R: cheese made from raw milk. P: cheese made from pasteurized milk. Color version available online.

Table 1. Proximate analysis on mean values of samples taken at 2 mo postmanufacture

Cheese	Region	Treatment	Collection	%				
				Fat	Moisture	Protein	Salt	pH
F1.R	Willamette Valley	Raw	Single	34.72	33.34	26.40	1.56	5.42
F1.P	Willamette Valley	Pasteurized	Single	33.69	34.55	26.08	1.67	5.31
F2.R	Willamette Valley	Raw	Single	33.41	34.55	26.63	1.69	5.25
F2.P	Willamette Valley	Pasteurized	Single	33.37	34.65	26.32	1.61	5.32
F3.1.R	Willamette Valley	Raw	Single	34.43	33.04	26.11	1.58	5.43
F3.1.P	Willamette Valley	Pasteurized	Single	33.43	33.78	26.69	1.69	5.41
F3.2.R	Willamette Valley	Raw	Single	34.44	33.52	26.00	1.54	5.40
F3.2.P	Willamette Valley	Pasteurized	Single	33.20	35.25	26.09	1.55	5.32
R1.R	Coastal Range	Raw	Commingled	35.14	34.41	24.61	1.72	5.29
R1.P	Coastal Range	Pasteurized	Commingled	36.44	34.25	24.02	1.56	5.28
R2.R	Columbia Plateau	Raw	Commingled	35.97	33.58	23.50	1.60	5.20
R2.P	Columbia Plateau	Pasteurized	Commingled	35.98	33.87	24.35	1.66	5.33
Mean				34.52	34.07	25.57	1.62	5.33
SD				±1.15	±0.65	±1.12	±0.06	±0.07

Figure 3. Dendrogram of the hierarchical cluster analysis from the 3-D multidimensional scaling (MDS) output of consumer sorting at 5 mo into aging using Ward's Method of the Euclidean distances. Numerals above nodes are used to describe clustering. Cheeses were made with milk collected from the Willamette Valley (F1, F2, and F3), Coastal Range (R1), and the Colombia Plateau (R2) ecoregions. Milk from F3 was collected at 2 separate occasions. R = cheese made from raw milk; P = cheese made from pasteurized milk. Color version available online.

ized (R1.P and R2.P) samples from R1 and R2 grouped closely together, representing their perceptual similarity. The F1 and F2 samples formed a loose grouping positioned between the F3 grouping and the R1/R2 grouping. This signifies that these samples were not grouped together as often as the other groupings and therefore share some perceptual similarities to the other groupings represented on the spatial map.

Cluster analysis using Euclidean distances from the MDS coordinates was performed to objectively infer the relationships between the set of samples. The hierarchical dendrogram shows the relationships of similarity as each higher level represents a more crude measure of similarity (Coxon, 1999). Amalgamation was performed using complete linkage, which are determined by the greatest distance between objects from different clusters. Figure 3 shows 3 distinct clusters of samples were formed: cluster I was composed of the F3 duplicated samples, from Corvallis, Willamette Valley; cluster II included commingled samples containing the pasteurized and raw R2 samples, along with the pasteurized R1 sample; and cluster III was constituted the raw and pasteurized samples from F1 and F2 as well as raw

sample from R1. Relaxing the linkage criterion, cluster I merged with the cluster II before joining cluster III. This joining shows that the samples in cluster I and cluster II were closer on the MDS 3-D spatial map and thus perceptually more similar to one another than to the cluster III samples.

Testing at 9 Months

Consumer Sorting. Subjects formed 3 to 6 groups (mean: 4.29, SD: 0.90). The stress values for the 2-D and 3-D MDS solutions were 0.18 and 0.10, respectively. The 3-D MDS solution was again chosen due to the lower stress value, representing a better fitting model describing the relationships in the data (Figure 4).

Similar to the 5-mo MDS, the duplicate F3.1 and F3.2 samples were plotted close to each other. However, the separation was more prevalent between the pasteurized (F3.1.P and F3.2.P) and raw samples (F3.1.R and F3.2.R) along dimension 2. The F1.P sample closely neighbored the F3.1.P and F3.2.P samples. The F2.P, R1.P, and R2.P had close proximities to one another. The R1.P, R1.R, R2.R, F1.R, R1.R, and R2.R formed

Figure 4. Three-dimensional multidimensional scaling (MDS) spatial mapping of cheeses at 9 mo into aging. Cheeses were made with milk collected from the Willamette Valley (F1, F2, and F3), Coastal Range (R1), and the Colombia Plateau (R2) ecoregions. Milk from F3 was collected at 2 separate occasions. R = cheese made from raw milk; P = cheese made from pasteurized milk. Color version available online.

a loose grouping, and the R1.R and F2.R samples had the smallest distances between them.

Cluster analysis using Euclidean distances from the MDS coordinates using complete linkage for amalgamation revealed 3 main clusters across the samples (cluster IV, V, and VI), as shown in Figure 5. Cluster IV contained solely the raw samples from F1, F2, R1, and R2. Cluster V was made up mostly of pasteurized samples, including the pasteurized and raw samples from F3.1, the pasteurized sample from F3.2, and the pasteurized sample from F1. Within cluster V, the pasteurized F3.1 and F3.2 samples had the closest linkage before joining with the pasteurized F1 sample. Therefore, these samples were perceived as more similar to one another than the lone raw sample from F3.1. The last collection of samples, cluster VI, contained the pasteurized

samples from F2, R1, and R2 and the raw F3 sample. Relaxing the linkage criteria showed that cluster V and cluster VI coupled together. These clusters, which were both predominantly composed of pasteurized samples, were perceived as more similar than cluster IV, which was exclusively made up of raw samples.

DISCUSSION

Multiple factors affect milk composition and quality, which ultimately affect cheese characteristics. With so many confounding effects, it is challenging to separate milk sourcing and document its effect on the final cheese. Standardization was used to reduce as many confounding effects as possible, including cow breed and feed as well as cheese processing practice. We could not

separate the location of the milk as a single variable. Instead we suggest that other farm related parameters (e.g., age of cows, type of bedding, clean-in-place operating conditions) be considered part of *terroir* (*terroir* of the farm) for each milk source. This is consistent with current research that argues for an expansion of the definition of geographical indicators (Bowen, 2010) or the “holism” of *terroir* (Paxson, 2010).

Cheese

The dairy herds selected for this study were mainly composed of Jersey cows (from 86 to 100% of herds) to control for the variable milk compositions from different breeds. The small temporal window, during which milk collection occurred, served a dual purpose. The first was to control for any seasonal shift in milk composition, which can significant effect sensory properties of Cheddar cheese (Hickey et al., 2006). The second reason, for collecting while cows were at pasture, was that most discrepancies in the animal’s diet would be directly related to the area of production. Carpino et al. (2004b) found that supplementing pasture to a

TMR feed resulted in milk that produced cheeses with different sensory characteristics due to higher levels of aroma compounds. Likewise, Cornu et al., (2005) studied terpene profiles in Cantal and Saint-Nectaire-type pasteurized- and raw milk cheeses made with milk from herds on pasture. Both studies demonstrated a direct link between pasture feeding and cheese characteristics.

To control variables related to cheese manufacturing location, all 12 cheese samples were manufactured in a single location (Arbuthnot Dairy Center), following identical processes and ancillary ingredients, while standardizing the milk to a consistent protein-to-fat ratio. This ensured that differences in the final cheese were related to the milk and not the processing facility (Crow et al., 2001). This is an important consideration because Drake et al. (2008) determined that facility specific factors appeared to affect Cheddar flavor more than regional differences.

The level of macro-components between cheeses was not significantly different (Table 1). This is important because cheeses produced with variable fat and protein contents have altered sensory characteristics (Buchin et al., 1998; Singh et al., 2003). Therefore, the differ-

Figure 5. Dendrogram of the hierarchal cluster analysis from the 3-D multidimensional scaling (MDS) output of consumer sorting at 9 mo into aging using Ward’s method of the Euclidean distances. Numerals above nodes are used to describe clustering. Cheeses were made with milk collected from the Willamette Valley (F1, F2, and F3), Coastal Range (R1), and the Colombia Plateau (R2) ecoregions. Milk from F3 was collected at 2 separate occasions. R = cheese made from raw milk; P = cheese made from pasteurized milk. Color version available online.

ences found from the sensory panel may be attributed to other compositional factors such as aroma and flavor compounds. Results also displayed similarity in cheeses made from the same location, specifically within the Willamette Valley ecoregion, the blind duplicates (F3.1 and F3.2) grouped close together in cluster I, indicating that the cheese made from that milk had distinctive characteristic. Although these samples were from the same location, they were made on 2 separate occasions, demonstrating the repeatability of the sourcing location and cheese manufacturing process, which validates the testing procedure for milk made from pasture-fed Jersey cows.

Effect of Milk Sourcing

At 5 mo of aging, the milk source location influenced the perceived similarities of the final cheese flavor. Cheeses from F1 and F2 (5 km apart) formed cluster III, signifying that cheeses made from milk at these locations had fairly similar flavor that was unique to these farms. The F3 samples, made from milk sourced 80 km away within the same region, were found to poses different flavors, as shown by their grouping in cluster I. This suggests that neighboring farms share factors that affect milk characteristics; whereas milk from a farm within the same region (Willamette Valley), but 80 km away, shared no common characteristics. Although the 3 farms are within the same ecoregion (Figure 1) classified as Willamette Valley Prairie Terraces with similar average temperatures, there are subtle differences in soil types and precipitation, with Corvallis having more clay and an average of 9.4 cm more precipitation per year (Huddleston, 1982; US Climate Data, 2015).

This result provides preliminary support to the American foundation for local food that considers *terroir* to be farm based, in contrast to the European usage of *terroir* that applies to regions instead of individual farms (Paxson, 2010). Nevertheless it is important to note that our data do not demonstrate the existence of *terroir* associated with dairy farms in the Willamette Valley. Rather, the data confirm that consumers are able to group cheeses based on milk sourcing at this one specific point in time.

Effect of Commingling

Commingling is the mixing of milk from multiple dairy farms and is standard operating procedure within the US dairy industry. The commingling occurs within milk hauling trucks or milk silos or both at the manufacturing plants. The commingled milk samples from R1 and R2 were sampled directly from milk trucks.

Commingling of milk had an apparent effect of consumers' perceptions of the samples. Commingled samples appeared to overcome the effect of sourcing location. Cluster II contained the cheeses made from commingled milk (R1 and R2) from 2 locations that had the greatest separation in the study (320 km apart). This is attributed to the effect of mixing milk sources and thereby removing farm-to-farm variability. However, the raw sample from R1 was not part of cluster II. Although the effect of pasteurization was not powerful at 5 mo into aging, the R1.R sample was greatly different perceptually than the other commingled samples.

Effect of Aging

At 9 mo into aging, a clear shift occurred in the flavor of the cheeses in comparison to the 5-mo-aged cheese. Location and commingling seemed to have the greatest effect on flavor of 5-mo aged cheese, whereas pasteurization made little to no difference. Continued aging of the cheeses until 9 mo unveiled that pasteurization had the most profound effect on the perceived flavor of the cheeses.

Effect of Heat Treatment

As shown above, the effect of heat treatment was evident after 9 mo of aging. Location-based characteristics were still seen, specifically from the pasteurized samples from F3.1 and F3.2 (cluster V) and commingled samples from R1 and R2 also formed close alignment (cluster VI). However, there is a clear distinction between the pasteurized and raw samples. Pasteurized samples made up the majority of cluster V and cluster VI, which were more similar to each other than to cluster IV. The raw samples in cluster IV, as well as the raw F3.1 and F3.2 samples, clearly overcame the influence of location and commingling as the cheeses were aged. It is generally recognized that pasteurization affects cheese flavor across multiple cheese types (Chambers et al., 2010), with raw milk cheeses consistently having more intense flavors than the pasteurized milk counterparts (Buchin et al., 1998; Ortigos et al., 2005; Shakeel-Ur-Rehman et al., 2000).

It is important to mention that slight differences in cheese texture were observed in pilot testing. This was consistent with some of the panelists' notes, even after being prompted to group the cheeses based on the differences in flavor (i.e., taste and retronasal odor), disregarding textural differences. Nevertheless, it may be difficult for untrained panelists to disregard textural cues, especially because the sorting task is designed to discriminate samples based on overall similarity and

dissimilarity. Lawless et al. (1995) found evident textural influences in the sorting of a range of commercial cheeses with a large textural difference.

Summary

Several studies have examined the application of *terroir* into the American landscape (Trubek and Bowen, 2008; Paxson, 2010). These studies investigated the potential effects and challenges of implementing a *terroir* landscape similar to those found in Europe. However, these studies did not attempt to apply this concept to determine if consumers could objectively perceive *terroir*; an important concept because these are the individuals that will ultimately purchase and consumer the *terroir*-based products. This study was able to gauge that the general population could distinguish between Cheddar cheeses made from variable milk locations. For those situations where differences due to milk sourcing are unwanted, commingling milk sources provides a way to overcome the effect of the milk origin. Additional aging exposed that regardless of milk location or whether it was commingled, the thermal treatment applied to the milk before cheese making may ultimately have the most effect on final cheese flavor. This study serves as an exploratory attempt to understand *terroir* and its effect on milk sourcing and cheese. It is clearly challenging to demonstrate the existence of *terroir* due to the many confounding factors in dairy production and processing along with general uncertainty regarding the exact parameters that pertain to *terroir*. Furthermore, this study provides information obtained from one grazing season, and it would be important to establish if these trends are consistent over seasons and years. Thus, the topics of *terroir* and local food as they relate to dairy processing are wide open for future research.

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