Temperature Effects on the Development of Cheddar Cheese Flavor and Aroma[1]

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ABSTRACT

Cooling of freshly formed Cheddar cheese is thought to be one of the processing steps that requires tighter control to achieve more uniform and consistent product quality. Cheese samples, obtained after pressing, were rapidly cooled to 5, 15, 25, or 35°C. Commercial samples and test cheese at 7, 30, 60, 90, and 120 d of ripening were evaluated by a trained descriptive panel. Most sensory characteristics of experimental cheese increased in intensity as a function of the interaction of time and temperature. The perception of sour and salty taste was affected by temperature but at equal rates over time. Buttery aroma and flavor tended to decrease in intensity as a function of time and temperature.
(**Key words**: flavor, Cheddar, temperature, aging)

INTRODUCTION

Cheese ripening has been defined as the controlled decomposition of a rennet coagulum of milk constituents (17). As this process occurs, a balance of taste and aroma (flavor) compounds is formed. The nature of this process is influenced in part by the microflora of the cheese. Controlled activity of cheese microflora is an important factor in prevention of off-flavor and aroma development (9, 18). Conditions that favor the die-off of starter bacteria (*Lactococcus lactis* ssp. *cremoris*) prior to complete lactose utilization open the way for formation of off-flavors such as sour flavor. Heterofermentative metabolism of lactose by nonstarter bacteria produce formic acid, ethanol, and acetic acid as by-products (13). Excesses of these compounds can impair the flavor balance of Cheddar cheese (28). Rapid cooling of cheese blocks to ripening temperatures is the primary means of control for microflora activity and thus promotes homofermentative metabolism (9). Law and Sharpe (16) found that ripening temperature was the most important single factor affecting Cheddar flavor intensity. Their data suggest that higher ripening temperature promotes faster flavor development.

Conochie and Sutherland (7) found a correlation between occurrence of cheese flavor defects and uneven cooling of blocks of Cheddar that had been stacked closely on pallets. After pressing, these blocks are still warm and are insulated to the inside of the pallet. In a survey of Cheddar cheese manufacturers conducted in 1969, it was concluded that lack of control in the cooling step from pressing to curing was responsible for considerable variation within lots (39). This can lead to various off-flavor defects. Experienced cheese graders have been reported to critique 30 to 40% of all American Cheddar cheese as being high acid (sour) and bitter (aged cheese) in off-flavor (4, 5). Miah et al. (27) studied the effects of four pressing and cooling treatments on flavor defects. They found a higher incidence of off-flavors associated with slower cooling rates. Aston et al. (2) studied the effect of ripening temperature (6 and 13°C) on flavor preference. They concluded that higher temperature ripening for longer periods was associated with

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lower preference scores. Production of strong off-flavors was cited as the cause of low preference scores compared with a standard.

The temperature of the posthoop cheese block ranges between a high of 35°C at pressing to the temperature at ripening (3.5 to 12°C). During the cooling period, a temperature gradient is established within the block of cheese (31). The rate of cooling of any given point within a cheese block will depend, in part, on the temperature profile over time at that point. The effect on sensory characteristics will be some function of the combined effects at the various temperatures within the profile. The purpose of this study was to define and quantify the effect on the sensory characteristics of constant cooling temperatures varied along the general range of processing temperatures (i.e., 5 to 35°C).

MATERIALS AND METHODS

Experimental Design

Eighteen-kilogram (40-lb) Cheddar cheese blocks produced from flash-heated milk by a large regional processor (Tillamook County Creamery Assoc., Tillamook, OR) were cut directly after the pressing operation into pieces measuring 6.4 cm × 8.9 cm × 14.6 cm (2.5" × 3.5" × 5.75"). Each piece was vacuum shrink-wrapped in commercial O_2 barrier cheese film. Samples were placed into incubators at 5, 15, 25, and 35°C. The total time elapsed from cutting to equilibration at incubator temperature was less than 5 h. Samples were randomly assigned to the four storage temperatures and tested at 7, 30, 60, 90, and 120 d, except 35°C cheese samples, which were discontinued from testing after 60 d.

The first two of the six batches of cheese sampled were used for training and preliminary investigation. The four batches used for testing were collected 1 wk apart during June 1989. The batch 4 cheese stored at 35°C was not tested at 60 d because of the development of intense off-odors that hindered proper evaluation of the samples.

Descriptive Panel

A descriptive panel of nine individuals was selected for participation in the project. Panelists developed a list of descriptors to characterize a variety of commercial and experimental samples. These samples included commercial and preliminary test samples selected to represent the range of sensory characteristics anticipated in the study (Table 1). Reference standards were selected for many of the descriptors (Table 2). A 16-point hedonic scale anchored with intensity descriptors (0 = none, 15 = extreme) was used to rate the intensity of the characteristics. Intensity reference standards were used to reduce variability among panelists [Table 3, (28)]. A ballot was developed to use in training the panel and later to test the cheese.

Blind-coded test samples of each storage temperature were served in random order to panelists in isolated sensory booths. Red lights were employed to mask appearance differences among cheese samples. Cheese blocks were tempered to 10 to 12.8°C before serving. A cheese core trier was used to obtain, immedi-

TABLE 1. Descriptors for Cheddar cheese characteristics.

Aroma	Flavor
Overall intensity	Overall intensity
Buttery	Sour
Nutty	Salty
Fruity	Bitter
Pungent acidic	Sweet
Pungent sulfur	Buttery
Sulfur	Nutty
Goaty	Fruity
Dirty	Goaty
Yeasty	Dirty
	Sulfur

TABLE 2. Aroma reference standards for Cheddar cheese.

Aroma characteristic	Reference standard[1]
Nutty	Lightly roasted filberts, 6 to 7 nuts
Buttery	Unsalted Land 'O Lakes[2] butter, ca. 20 g
Fruity	Chopped overripe pineapple, ca. 20 g
Pungent acidic	1.0% Formic acid in distilled H_2O
Goaty	.1% Butyric acid in distilled H_2O
Dirty	.1% Isovaleric acid in distilled H_2O

[1]All served in wine glasses covered with watch glasses.

[2]Minneapolis, MN.

TABLE 3. Aroma and flavor intensity standards for Cheddar cheese.

Scale value	Descriptor	Intensity standard
Aroma		
3	Slight	Saffola safflower oil (30 g)
7	Moderate	Hi-C[1] orange drink (18 g)
11	Large	Welch's[2] grape juice (18 g)
15	Extreme	Big Red[3] cinnamon bubble gum (1 stick)
Flavor		
6	Sour	.05% Lactic acid in spring H_2O
6	Bitter	.05% Caffeine in spring H_2O
6	Salty	.5% NaCl in spring H_2O

[1]Coca Cola Foods, Houston, TX.

[2]Concord, MA.

[3]Wrigley Jr. Co., Chicago, IL.

ately prior to serving, samples (1.3-cm diameter by 6.4-cm length) free of surface oxidation artifacts. Servings were placed in covered plastic containers for immediate presentation to panelists.

Statistical Analysis

Data were analyzed through analysis of variance techniques with a compound *F* test as described by Schultz (34). Temperature, age, batch, and panelist were established as the main effects. Temperature and age were treated as fixed effects. Batch and panelist effects, because they were viewed as a representative sampling from a population, were treated as random effects (23). Estimates of mean square values were generated using the general linear models procedure for unbalanced data on the SAS statistical software package (Version 6.02, SAS Institute Inc., Cary, NC) on an IBM system 4381 (IBM Corp., Boca Raton, FL). The objective was to study the effects of temperature and age concurrently. For that reason, all descriptors were first tested for the interaction of age and temperature using the general linear models procedure for unbalanced data on the entire data set. For those descriptors found to be nonsignificant ($P > .05$) for the interaction effect of temperature and age, a second test was run for the effects of age and temperature alone. In these cases, the mean squares values were generated on data collected at all storage temperatures through 60 d of testing only. This was done to prevent introduction of a bias from 90- and 120-d measurements.

Because of the biased nature of the missing data point for batch 4, kept at 35°C for 60 d, a synthetically derived, biased estimate of the treatment by age mean for 35°C at 60 d was required (10). This was accomplished by calculation of an estimate of the error terms associated with values for complete blocks of batch by temperature means. These values were then substituted back into the model equation for point estimation of the missing value (batch 4, 35°C). This value was then used to calculate the corrected mean value at 35°C and 60 d (L. Calvin, Department of Statistics, Oregon State University, personal communication). These values are used in this analysis where temperature, age, and temperature by age means are reported.

Least significant differences values were used to determine differences between the means where significance ($P < .05$) was established by the type 1 compound *F* test for temperature, age, and treatment by age effects. These values were calculated using a type 2 *F* test and a *t* value at 5%.

RESULTS AND DISCUSSION

Commercial Cheese Evaluation

During the later stages of training, the panel was asked to evaluate samples of commercial medium sharp cheese. These samples were manufactured by the same supplier as were the test cheeses (Table 4). A formal study of the characteristics of commercial Cheddar is not

TABLE 4. Mean intensity ratings (0 = none, 15 = extreme) for aroma and flavor characteristics of three samples of commercial medium sharp Cheddar.

	Intensity scores		
	Sample		
Characteristics	1	2	3
Aroma			
Overall intensity	7.4	6.4	6.8
Buttery	5.4	4.6	5.3
Nutty	4.0	2.8	4.1
Fruity	2.8	2.0	2.0
Goaty	2.1	2.9	1.3
Flavor			
Overall intensity	6.9	7.4	7.1
Sour	4.9	5.4	5.8
Salty	4.9	5.4	5.8
Bitter	4.9	4.3	4.5
Sweet	1.9	1.3	1.0
Buttery	3.9	3.8	4.1
Nutty	2.3	1.4	2.8
Fruity	1.4	1.4	1.6
Goaty	1.3	1.3	1.0

consistent with the objectives of this study. However, the values shown here have been helpful in the relative evaluation of the test cheese to follow.

Temperature by Age Interaction Effects

All aroma and flavor characteristics were significant for temperature by age interaction except nutty aroma and nutty, sour, and salty flavors (Table 5). Nutty aroma showed no significance at less than 5% for either treatment effect. Nutty, sour, and salty flavors were significant for the effects of both age and temperature.

All characteristics that showed significance because of some treatment effect generally showed increasing intensity with increasing age, temperature, and age by temperature. The exception to this was buttery aroma and flavor, which generally decreased with increasing age by temperature interaction.

Overall Intensity of Flavor and Aroma

Initial testing for the significance of the interaction of temperature and age has the advantage of revealing the relationship between any two conditions of temperature and age. This is not the case when the temperature or age effect are tested independently. Thus, the latter was used only when the interaction effect was nonsignificant. Table 6 gives temperature by age statistics for overall aroma intensity. These means are represented graphically in Figure 1a. At the first test period (7 d), the difference in the means for overall aroma intensity was significantly higher at successively higher temperatures. This trend continued through 120 d. The cheese stored at 5°C increased only slightly in overall aroma intensity score from 7 to 120 d. The cheese aged at 15°C followed a similar pattern but at higher average intensity scores and with a slightly greater overall increase in intensity. The cheese aged at 25°C increased in overall intensity through 90 d but showed no significant change after that. The cheese aged at 35°C increased in overall intensity through 30 d but showed no significant change between 30 and 60 d.

In general, overall flavor intensity followed the same patterns as did the overall aroma intensity but to a greater degree of both intensity and rate of increase (Figure 1b). Flavor intensity was perceived at slightly lower levels at the first test period but generally increased at greater rates throughout ripening. At the last test period (120 d), cheese was higher in flavor intensity than aroma intensity. Again, the cheese stored at 35°C showed less increase in flavor intensity between 30 and 60 d than between 7 and 30 d.

The commercial samples evaluated during training (Table 4) had a range of aroma and flavor intensity equivalent to experimental samples ripened between 5 and 15°C for 60 d. This is consistent with the actual manufacturing practices of the processor; pallets of 18-kg cheese blocks are ripened in a room at 3.3 to 4.4°C for a minimum of 60 d. The experimental cheese ripened at 35°C was significantly higher in overall flavor and aroma intensity at 7 d than the 15°C, 60-d-old cheese (i.e., the one similar to commercial cheese samples). This observation adds perspective and emphasis to how rapidly high temperature ripening affects cheese flavor characteristics. Aston et al. (2) also found total flavor to be a function of time and temperature. Their findings corroborate the conclusion of Law and

TABLE 5. The *F* statistic significance levels for Cheddar cheese descriptors.[1]

Characteristics	T	A	T × A	P	P × T	P × A	P × T × A
Aroma							
Overall intensity	. . .[2]	. . .	*	***	. . .	. . .	***
Buttery	. . .	. . .	***	***	. . .	. . .	NS
Nutty	NS	NS	NS	***	. . .	. . .	. . .
Fruity	. . .	. . .	**	***	. . .	. . .	NS
Pungent acidic	. . .	. . .	**	***	. . .	. . .	NS
Pungent sulfur	. . .	. . .	*	***	. . .	. . .	NS
Goaty	. . .	. . .	***	***	. . .	. . .	NS
Dirty	. . .	. . .	***	***	. . .	. . .	**
Yeasty	. . .	. . .	**	***	. . .	. . .	*
Flavor							
Overall intensity	. . .	. . .	***	***	. . .	. . .	NS
Sour	***	**	NS	***	***	***	. . .
Salty	***	*	NS	***	***	***	. . .
Bitter	. . .	. . .	***	***	. . .	. . .	**
Sweet	. . .	. . .	*	***	. . .	. . .	***
Buttery	. . .	. . .	***	***	. . .	. . .	NS
Nutty	*	*	NS	***	***	***	. . .
Fruity	. . .	. . .	*	***	. . .	. . .	***
Goaty	. . .	. . .	***	***	. . .	. . .	*
Dirty	. . .	. . .	***	***	. . .	. . .	**
Sulfur	. . .	. . .	***	***	. . .	. . .	**

[1]T = Temperature; A = age; P = panelist.

[2]Not tested.

*$P < .05$.

**$P < .01$.

***$P < .001$.

Sharpe (16) that maturation temperature is the most important factor in determining flavor intensity.

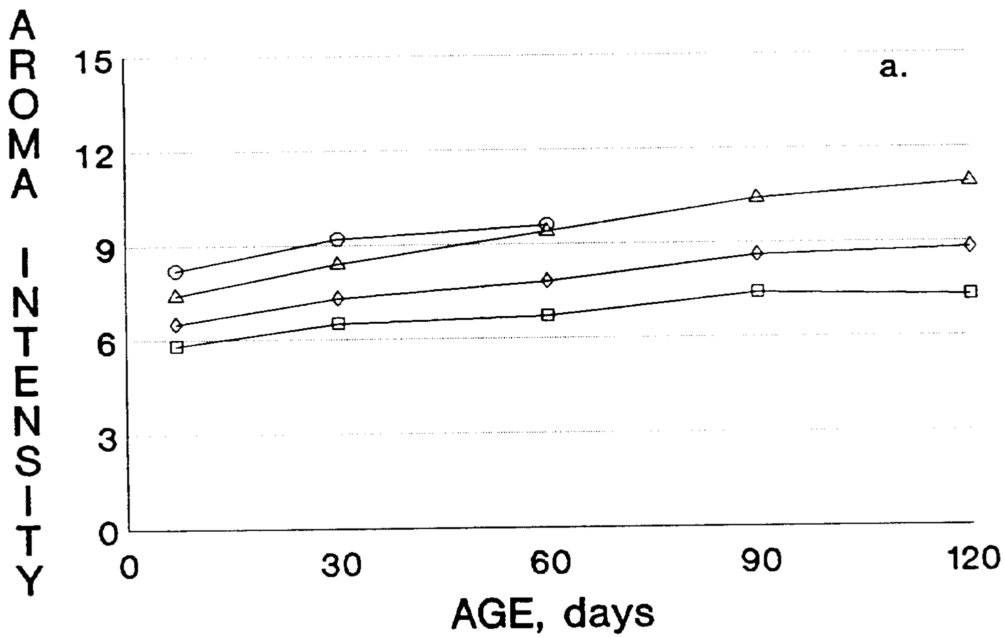
A recent review (18) of the role of starter bacteria concluded that enzymes from both viable and nonviable starter cells are contributing factors in flavor development in Cheddar cheese. Various studies of the contribution of nonstarter bacteria to flavor development have shown that cheese made in open vats develops an overall intensity of Cheddar flavor more rapidly than experimental cheese containing populations of exclusively starter culture microorganisms (32). In addition, the densities of nonstarter bacteria are quite important (19), particularly in the early stages of ripening. The

TABLE 6. Interaction of temperature and age on overall aroma intensity.

	Intensity means for all panelists								
Days	5°C		15°C		25°C		35°C		LSD[1]
		SD		SD		SD		SD	
7	5.79[a]	1.43	6.53[b]	1.45	7.39[d]	1.34	8.22[ef]	1.66	.67
30	6.5[b]	1.48	7.25[cd]	1.40	8.43[f]	1.64	9.24[gh]	1.84	
60	6.71[bc]	1.66	7.76[de]	1.61	9.38[gh]	2.33	9.57[h]	1.96	
90	7.40[d]	1.45	8.56[f]	1.66	10.43[i]	1.97			
120	7.25[cd]	1.40	8.78[fg]	1.61	10.92[i]	2.40			

[a,b,c,d,e,f,g,h,i]Means with the same letter are not significantly different ($P < .05$).

[1]LSD = Least significant difference.



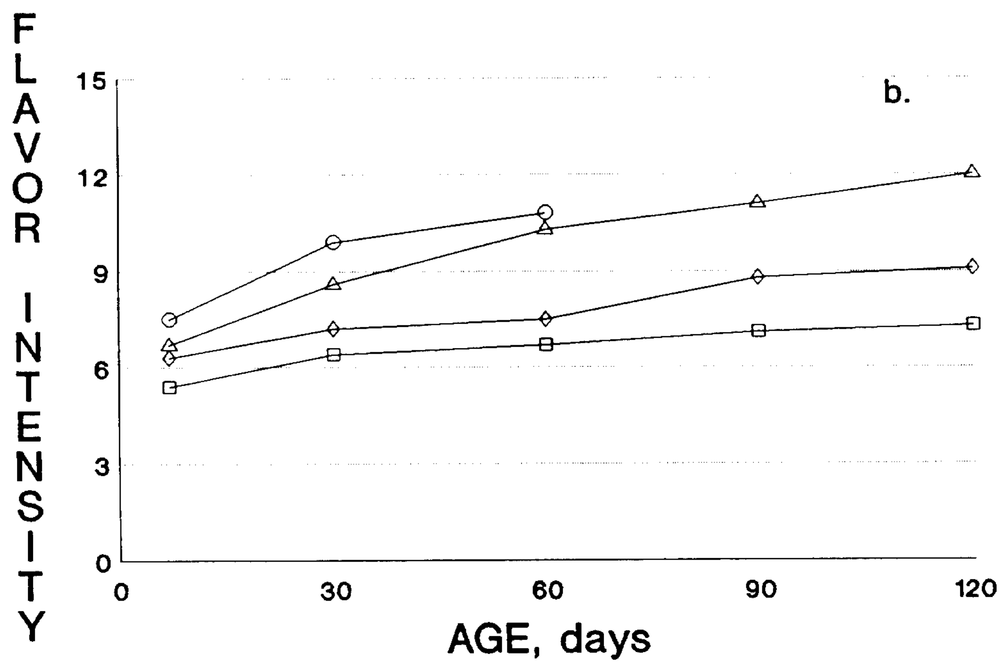


Figure 1. Mean overall aroma (a) and flavor (b) intensity scores as a function of time and temperature (□ = 5°C; ◊ = 15°C; Δ = 25°C; ○ = 35°C).

TABLE 7. Mean sour and salty intensity scores for the effect of temperature and age on test Cheddar cheese at 7, 30, and 60 d.

	Temperature				Age		
	5°C	15°C	25°C	35°C	7 d	30 d	60 d
Sour	4.75[a]	5.89[b]	6.26[b]	6.89[c]	4.91[a]	6.21[b]	6.40[b]
Salty	4.34[a]	4.85[b]	5.24[c]	5.38[c]	4.50[a]	5.01[ab]	5.38[b]

[a,b,c]Means followed by the same superscript letter are not significantly different ($P < .05$).

experimental cheese in this study exhibited increasing growth rate of nonstarter bacteria as a function of temperature (10). This correlates to the observations of the panel concerning the increase in overall aroma and flavor intensity with increasing time and temperature.

Sour Taste

The interaction of temperature and age on sour flavor was not significant. However, the F value for differences in the effect of temperature only at 7, 30, and 60 d showed significance. Sourness generally increased with an increase in temperature, except that no significant difference was found between the average intensity at 15°C and that at 25°C (Table 7). The F value also showed significance for the difference between age means. Sourness increased in intensity only between 7 and 30 d. These results are in general agreement with chemical profiles reported by Bouzas (6).

The proportion of residual lactose (unmetabolized) is highest in Cheddar curd at the beginning of the cooling process. Starter bacteria are not entirely inhibited by the salting process, and this microflora can be expected to continue to metabolize lactose (19). In addition, nonstarter bacteria, such as lactobacilli and pediococci, affect the rate of metabolism of lactose. Turner and Thomas (38) found that the temperature of cooling played an important role in the rate of lactose metabolism during aging. These investigators found that, at 22°C, residual lactose in Cheddar was utilized more than twice as fast as when cheese was cooled immediately to 12°C. Thus, our observations that perceived sourness was generally a function of temperature (cooling rate) and that increased sourness was most readily noted during the early stages of ripening (when metabolism of lactose was greatest) are consistent with the findings reported by other researchers (8).

More rapid growth of nonstarter bacteria encourages heterolactic fermentation of lactose as well (19). Production of acetic acid in addition to lactic acid through microbiological activity contributes to overall sourness.

Bitter Taste

At the first test period (7 d), the cheese stored at 35°C is significantly higher in bitter flavor, and the one kept at 5°C was significantly lower than the cheese aged at 15 and 25°C (Figure 2a). The rate of increase is higher with cheese stored at successively higher temperature with significant differences in all temperatures at all ages beginning at 30 d. The experimental cheese ripened at 25 and 35°C was significantly higher in bitter flavor at 60 d than commercial cheese that had been ripened for 60 d or longer.

Bitterness in Cheddar cheese has been attributed to the proteolytic breakdown of casein to peptides that manifest a bitter taste. Rennet is largely responsible for hydrolysis of casein to nonbitter, high molecular weight peptides. Starter bacteria peptidases reduce these intermediate products of proteolysis to bitter, low molecular weight peptides (29). Intracellular peptidases released during die-off of the starter bacteria are largely responsible for this activity (20). Accelerated die-off of starter bacteria with increasing ripening temperature (10) can be expected to contribute to the more rapid development of bitter flavor. In addition, nonstarter bacteria, particularly the lactobacilli, contribute to proteolysis by conversion of proteins into small peptides (22, 29, 33). Lee et al. (21) found that several species of lactobacilli added to the starter culture during cheese manufacture resulted in bitterness compared with starter culture that contained only *Lactococcus* species. It is this species-specific proteolytic activity that may explain why some research-

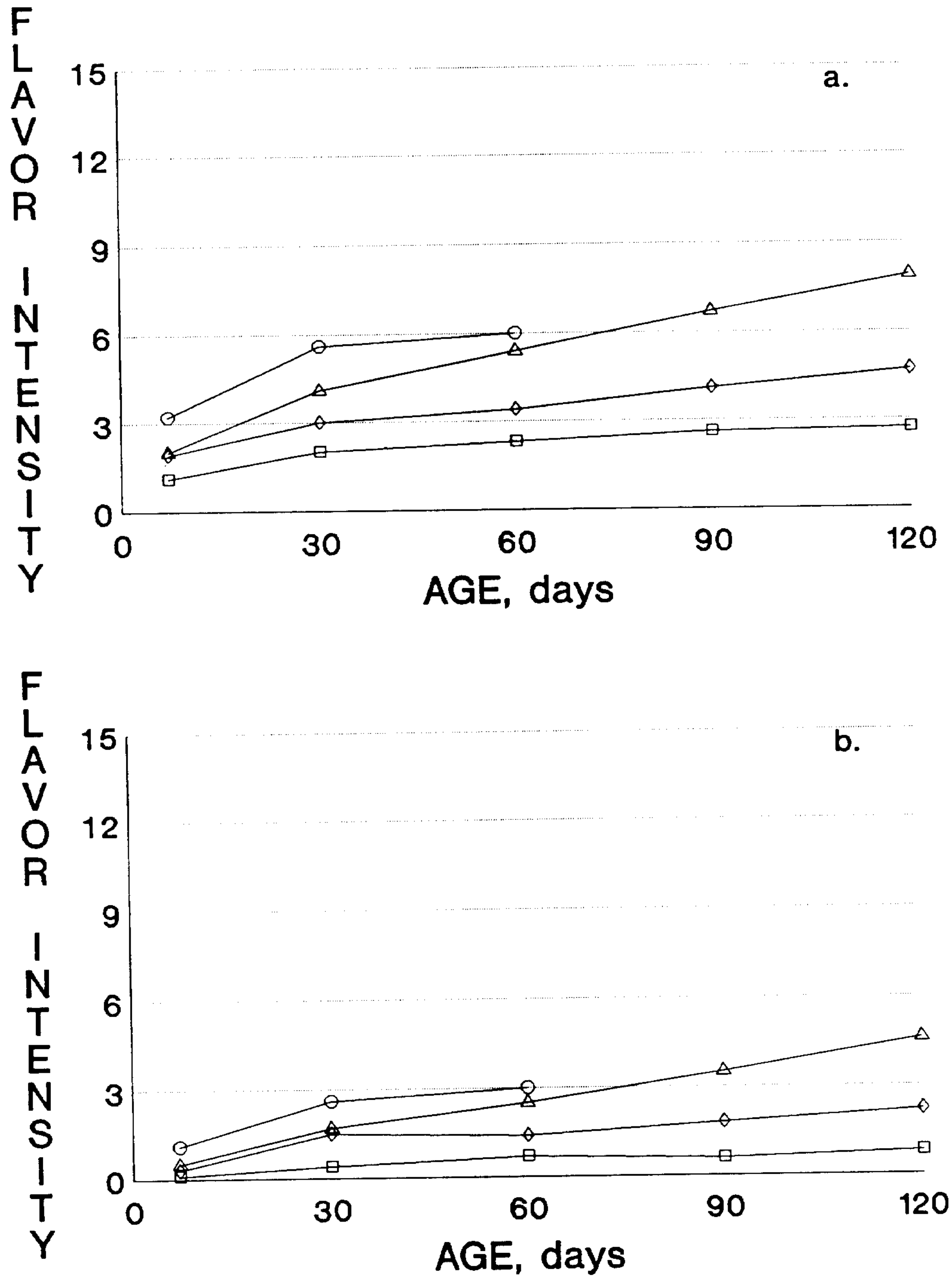


Figure 2. Mean intensity scores for bitterness (a) and sulfur (b) as a function of time and temperature (□ = 5°C; ◊ = 15°C; Δ = 25°C; ○ = 35°C).

ers report a decrease in bitterness with time but others report an increase (3, 16).

Sulfur Aroma and Flavor

Sulfur flavor was perceived to be a very minor component in cheese at 7 d, reaching just detectable levels in the 35°C storage temperature cheese only (Figure 2b). At 30 d, the cheese at 5°C was lower in sulfur-like flavor, and the one at 35°C was higher than those at 15 and 25°C. At 60 d, the cheeses stored at 25 and 35°C were higher than the others. At 90 and 120 d, intensity increased with increasing temperature. The means for pungent sulfur aroma showed the same trend of development as sulfur flavor but at lower intensity levels (10). The intensity of pungent sulfur aroma ranged from .97 (just detectable) to 4.19 (little more than slight).

Volatiles are an essential factor in Cheddar flavor (25). The literature on the contribution of sulfur compounds to Cheddar flavor has been conflicting. Headspace analysis has shown a strong correlation between sulfur-containing volatiles (H_2S, methanethiol) and the presence of normal Cheddar aroma (11, 15). However, another study concluded that sulfur compounds are not good indicators of flavor development (1).

Starter bacteria have been found to contribute to the sulfur note in Cheddar flavor. The means is through development of the proper conditions of pH and redox potential and the production of precursors to the formation of volatile sulfur compounds (14). Nonstarter bacteria have also been found to contribute to redox potential conditions to varying degrees (37). In this study, sulfur aroma and flavor characteristics tended to increase with increasing age and temperature of cheese maturation. These findings are consistent with the microbiology studies by Grazier (10) on experimental Cheddar cheese samples.

Goaty and Dirty Flavor and Aroma

At 7 d, the 35°C storage temperature cheese was higher in goaty flavor, and the cheese at 5°C was lower in this character, than cheese at any other storage temperature but same age (Figure 3a). Cheese ripened at 35°C was already significantly higher in goaty flavor than the commercial cheese tested, which was rated just detectable. Eventually, cheese aged at 25 and 35°C reached a level of goaty flavor that coincided with slight to moderate on our scale. The cheese stored at 5°C showed no real change in goaty intensity over the total test period with goaty flavor judged to be just detectable. Goaty aroma showed trends similar to goaty flavor but to a lesser degree of intensity. Dirty-like aroma and flavor followed trends similar to goaty flavor but generally with somewhat less intensity (Figure 3b).

Low molecular weight free fatty acids ($<C_4$) are produced by lactic acid bacteria during ripening (36). The most important of these is butyric acid, which was the reference compound used by the panelists to describe goaty flavor and aroma. Stadhouders and Veringa (35) suggested that the longer fatty acids ($>C_4$) were produced through deamination of amino acids (e.g., isovaleric acid from valine). Lamparsky and Klimes (12) identified isovaleric acid as a constituent of Cheddar flavor. Dilute isovaleric acid was chosen by the panelists as characteristic of dirty flavor and aroma. Puchades et al. (30) showed that valine was one of the principal amino acids liberated through proteolytic activity of starter and nonstarter bacteria. Increase in temperature from 6 to 15°C intensified proteolysis. Some strains of lactobacilli have been associated with a reduction of valine levels during the latter stages of ripening. The authors suggested that this reduction is associated with reactions occurring in the cheese resulting in the formation of deamination products (30).

Pungent Acidic Aroma

The development of a pungent acidic aroma followed a similar trend to goaty and dirty characteristics, increasing in intensity as a function of increasing time and temperature (Figure 3c). The panelists associated this aroma with that of dilute formic acid. Fryer (9) suggested that control of the growth of nonstarter lactic acid bacteria (*Lactobacillus, Pediococcus*) through rapid cooling to 10°C prevented the heterofermentative metabolism of lactose.

Fruity Aroma and Flavor

Fruity flavor was determined at just detectable levels (.66 to 1.44) at 7 d and at all temperatures. The cheese aged at 5°C remained

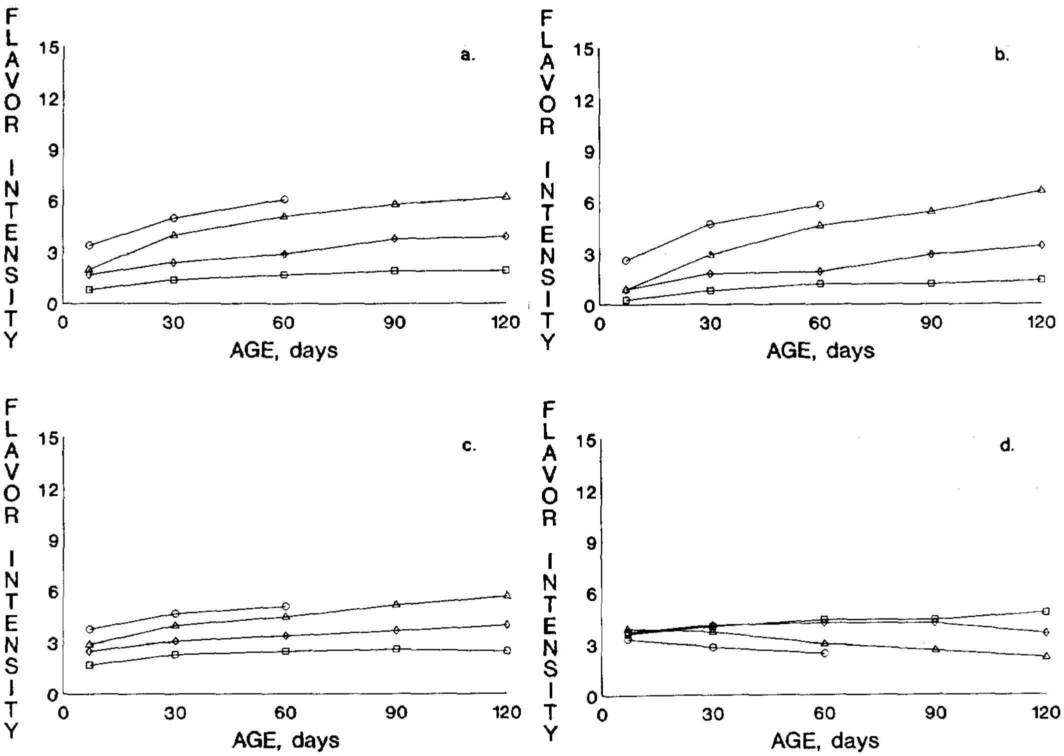


Figure 3. Mean intensity scores for goaty flavor (a), dirty flavor (b), pungent acidic aroma (c), and buttery flavor (d) as a function on time and temperature (□ = 5°C; ◊ = 15°C; Δ = 25°C; ○ = 35°C).

at or below just detectable levels throughout the test period (10). All other samples increased in intensity as a function of time and temperature, reaching an intensity range of 1.1 to 3.7 for final test periods (10). Fruity aroma showed similar trends (10). Commercial samples ranged slightly over the just detectable level, which was less than the cheese aged at 35°C for 30 d.

Conochie and Sutherland (7) found that fruitiness is often a function of ripening temperature. Manning (24) showed a correlation between the fruity flavor characteristic and the ethanol content in the headspace. Thomas et al. (36) associated the production of ethanol with heterofermentative metabolism of lactose by nonstarter bacteria in the early stages of ripening at higher temperatures. This study showed that the samples aged at 5°C did not increase significantly in fruity intensity during ripening. This finding supports Fryer's (9) contention that rapid cooling to 10°C prevents heterofermentative activity.

Salty Taste

No significance was found in the value of the F statistic for the interaction of temperature and age. As with sourness, this indicates no difference in the rate of development of a salty flavor characteristic as a function of time and temperature. However, significance was detected in the F value for temperature and age effects alone. The analysis of the means for these treatments indicated a perceived saltiness increasing in intensity through the 25°C storage temperature (Table 7). Saltiness also appeared to increase gradually with age, contrary to what was expected.

Sweet Taste

Sweetness was judged to be a minor component in the experimental cheese. Differences in the intensity of the temperature treatments over time only became apparent at 60 d. The cheese aged at 25 and 35°C was significantly higher in sweetness intensity than the one aged at 5 and 15°C through 60 d. The cheese aged at 25°C continued this trend through 120 d. In the case of cheese aged at 5 and 15°C, there were no substantial changes perceived through 120 d, and scores ranged from 1.31 to 2.14 in sweetness intensity. The cheese aged at 25°C gradually increased through 120 d to a maximum intensity score of 3.42 (slight). This was significantly higher than the 5 and 15°C storage temperature cheese by 60 d. The cheese aged at 35°C increased in sweetness intensity between 30 and 60 d. Changes in perceived sweetness may have been associated with fruitiness perception rather than carbohydrate content, because the latter decreases over time (17).

Buttery Aroma and Flavor

At 7 d, no difference in buttery flavor was perceived among any of the storage temperatures (Figure 3d). Thereafter, the cheese stored at 25 and 35°C declined in buttery flavor as a function of time and temperature. The cheese stored at 15°C was not perceived as significantly different from the cheese aged at 5°C until the last test period (120 d) when the buttery intensity was slightly less. Generally, buttery aroma followed the same trend and was perceived at similar intensity levels.

In the cheese tested earliest, buttery was perceived as one of the more dominant flavor components. As aging continued, the intensity of perception decreased at rates consistent with higher temperature treatment. This phenomenon is perhaps due to 1) a masking effect by other components of increasing intensity; 2) alteration of the compounds responsible for buttery flavor, which resulted in loss of perception; or 3) a combination of both of these factors.

Nutty Aroma and Flavor

The *F* values for the interaction of temperature and age on nutty flavor and aroma were not significant. The *F* statistic for the effects of age or temperature was significant to 5% only, and intensity ratings overall for nutty flavor were less than slight. As expected, nutty aroma was judged to be of only slight intensity throughout the 120 d of ripening time for all temperatures. No significance was found for the effects of storage temperature, age, or temperature by age interaction on nutty aroma. Thus, although present, nuttiness was not perceived as a major factor during ripening. This was generally consistent with the nuttiness level perceived in the commercial cheese samples.

Yeasty Aroma

Yeasty aroma was perceived as undetectable by most of the panelists except in the cheese stored at 25 and 35°C after 60 d. In these samples, it was judged to be just detectable.

Panelist Effect

The panelist effect was tested and found to be significant for all flavor and aroma characteristics; this implies that panelists were using different parts of the scale to define the given intensity of the perceived characteristic. The *F* tests for the interaction of panelists by temperature by age were found to be significant for several of the descriptors. These descriptors also showed significance for temperature by age interaction (Table 5). Descriptors that were significant for the effects of temperature or age alone were also significant for the interactions of temperature by panelist and age by panelist (Table 5).

Although panelist by treatment interaction was present for several of the descriptors, usually individual panelists agreed with the general trends as indicated by average values. With certain descriptors (overall aroma intensity, dirty aroma, sour, bitter, goaty, dirty, and sulfur flavors), significance of the interaction effect appeared to be related to how an individual panelist perceived the relative magnitude of the intensity on the 16-point scale. For example, one panelist may have perceived that the rate of increase of intensity with storage temperature over time was greater or less than the rate perceived by other panelists. This means that various panelists were using differences between parts of the scale in relatively different ways.

With three of the flavor descriptors (salty, sweet, fruity) confusion appeared to exist among panelists about the relative perception of these characteristics. Some panelists described increasing intensity with increasing temperature over time; others described decreasing intensity or no change. In describing intensity of yeasty aroma, some panelists consistently scored this characteristic as not present in all or most of the samples. This may have indicated below threshold levels or panelist confusion in identifying this particular characteristic.

CONCLUSIONS

The characteristics analyzed in this study represent an extensive description and quantification of the aroma and flavor profile of experimental Cheddar cheese by a trained sensory panel. In general, flavor and aroma intensities of the experimental cheese increased as a function of time and temperature; exceptions to this were the nutty and buttery aroma and flavor characteristics. Many of these sensory characteristics are closely associated with microbiological changes, which were also correlated to time and storage temperature (10).

Mean intensity scores for overall aroma and flavor intensity reflected the changing character of the cheese early in the ripening phase. Flavor and aroma intensity was described by the panelists as being in the moderate range and increasing with the given storage temperature. The main components (more than slight) of the flavor at 7 d were sour, salty, and buttery flavor and aroma. Secondary characteristics (slight) included goaty flavor and aroma, pungent acidic aroma, nutty flavor and aroma, and bitter flavor. All others tested were judged to be at threshold levels with the exception of yeasty. This component was not detected by most panelists.

As overall intensity increased with time, so did bitter flavor, goaty aroma and flavor, dirty aroma and flavor, pungent acidic aroma, sulfur flavor and aroma, and fruity aroma and flavor. These trends reflected the growing complexity of the cheese character with time and temperature. These components reached or exceeded levels consistent with the initial main components of sour, salty, and buttery aroma and flavor. The latter tended to stabilize or decrease in the presence of the other components. This study reflects the importance of temperature on the desirable characteristics of Cheddar cheese aroma and flavor. Several components (bitter, goaty, dirty, fruity) are integral to the overall character of Cheddar as reflected by evaluations of commercial samples evaluated in this study. However, excessive levels prompted complaints by the panelists about the disagreeable character of some of the test cheese. Sensory evaluations at 7 d indicate that cheese stored at high temperatures quickly reaches intensity levels for these components unsuitable for commercial Cheddar cheese.

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