Research Article

Spatiotemporal Characterization of Texture of Crescenza Cheese, a Soft Fresh Italian Cheese

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Crescenza cheese is a soft fresh cheese without rind, typically manufactured using a high amount of rennet. It is characterized by a fast proteolysis that causes changes in texture and leads to the so-called defect of “colatura” that is the tendency of the matrix to freely flow in the outer part of the cheese and generate spatial inhomogeneities into the cheese. In this paper, the textural properties of Crescenza were evaluated for cheeses manufactured using two types of rennet and starter cultures. Cheese texture was monitored during a 3-week shelf life considering a possible spatial variability of the matrix. At the beginning of the shelf life, a certain spatial inhomogeneity was observed from the center to the edge of the cheese block for all the trials. The firmness decreases from the center to the outer part of the block. During storage, hardness showed a decrease during 1st wk of storage; moreover, from days 7 to 21, cheese increased its hardness in the center and decreased it in the outer part of the block, resulting in a higher spatial inhomogeneity of the cheese. The textural measurements can be a useful tool to define the quality of Crescenza cheese during shelf life.

1. Introduction

Cheese texture can be considered as one of the most important parameters for determining the quality and the identity of the cheese and to estimate the sensory appreciation of the structure [1–3]. During ripening and storage, the textural properties of various cheeses can deeply change as a result of biochemical processes and mass transfer phenomena. The temporal variability of several cheeses has been extensively discussed for parameters such as proteolysis and pH [4–6], moisture and salts [7, 8], texture [2], and microstructure [9]. For nonstretched fresh soft cheeses like Crescenza, the residual rennet activity has a main influence in leading proteolysis phenomena as other proteolytic agents such as enzymes from the starter bacteria have a limited action due to the short storage period [10]. As for the ripening time, also a certain variability of the chemical and physical properties associated with spatial nonhomogeneity could be present. Many authors studied the influence of the different location on several parameters: for instance, Simal et al. [11] described the diffusion of water and salts in the cheese matrix; Macedo et al. [12] described the spatial variability of microflora, lactic acid, NaCl, and moisture content of Serra cheese; Liu and Puri

[13, 14] studied the spatial variability of moisture and pH of Camembert. Also for textural properties, a spatial diversity could be present. In cheesemaking manufacture, steps, such as syneresis, brining, cooling, and ripening, can generate gradients of mass and/or heat that could contribute to the formation of a nonhomogeneous texture among the cheese geometry [4]. Moreover, also the storage time can influence the spatial nonhomogeneity; some spatial differences present at the end of cheesemaking can increase during storage, while other differences can be flattened [15]. Studies regarding the possible spatial nonhomogeneity of textural properties have already been reported in literature for different cheeses [4, 8, 15–18]. In these cases, the observed differences were mainly caused by moisture, NaCl, pH, and proteolysis gradients. On the contrary, the spatial nonhomogeneity has never been investigated for soft fresh cheeses characterized by a high moisture content, a fat to protein ratio higher than 1, and a short shelf life. In this case, cheese texture can quickly change during shelf life, becoming too soft and representing one of the limiting factors of cheese shelf life. Crescenza cheese is a soft cheese without rind, with moisture content generally higher than 58 g/100 g and a fat to protein ratio of about 1.5. Crescenza cheese is characterized by the absence of a

ripening period excluding a short time of refrigerated storage (up to 1 wk) at high relative humidity ($\approx 95\%$) necessary to develop its structure; its shelf life is usually shorter than 3 wks [19, 20]. One of the main defects of Crescenza cheese is called “colatura,” a softening of the texture given by primary proteolysis that leads the cheese to freely flow when not supported by the pack or when cut during consumption [19]. Traditionally, Crescenza cheese has been sold as whole cheese, portioned at the moment of selling, while today most of the cheese is sold prepackaged in portions from 80 up to 250 g. The change of structure is usually associated with casein breakdown mainly due to residual rennet activity [21], but no data are available about the spatiotemporal nonhomogeneity of its structure. The purpose of this study was then to investigate the possible spatiotemporal changes of Crescenza cheese's texture produced by means of different rennet and/or lactic acid bacteria starter cultures. Traditional calf rennet and fermentation-produced camel chymosin (FPCC), which has ratio between milk clotting activity and general proteolytic activity 7 times higher than calf chymosin [22], were used as rennet formulations in order to obtain different body texture between formulations.

2. Materials and Methods

2.1. Cheesemaking. As the changes in textural characteristics of Crescenza cheese could be affected by different LAB starters or coagulating agents used, three different types of Crescenza cheeses were manufactured at the CREA-ZA pilot dairy (Lodi, Italy) as follows:

(i) N: manufactured using a direct-to-vat starter culture of *St. thermophilus* (DVS® Direct Vat Set, Chr. Hansen Holding A/S, Horsholm, Denmark) and calf rennet (NATUREN®, Chr. Hansen Holding A/S, Horsholm, Denmark), with a strength of 109 international milk clotting units (IMCU)/mL and 90% minimum content of chymosin

(ii) C: manufactured using the same direct-to-vat starter culture of *St. thermophilus* of Crescenza N and a fermentation-produced camel chymosin (FPCC) (CHYMAX M®, Chr. Hansen Holding A/S, Horsholm, Denmark, 1,024 IMCU/mL)

(iii) S: manufactured using the same calf rennet of Crescenza N and a bulk starter culture of *St. thermophilus* (Sacco, Cadorago (CO), Italy) that was prepared the day before the cheesemaking trial inoculating 3 L of autoclaved milk (103°C per 15 min) at 42°C until a final acidity of $9^\circ\text{SH}/50\text{ ml}$ was reached

Whole milk used for the cheesemaking was collected from the CREA-ZA farm and its fat and protein content were standardized at 4.30% and 3.40%, respectively, by means of milk protein concentrate (MPC85 Solago, Glanbia plc, Kilkenny, Ireland) and fresh cream addition. The milk was pasteurized at $75 \pm 1^\circ\text{C}$ for 30 s with a plate heat exchanger (Milk Project, Merone, CO, Italy) just before the cheesemaking and for each cheesemaking process, 70 L of milk was used. 0.7 and 0.9 g/L of glucono delta-lactone were, respectively, used for Crescenza N and C to reduce the production time as no initial acidification was reached with direct-set starter. 20 grams of direct-set culture for

Crescenza C and N and 3 kg of bulk starter for Crescenza S were added to the milk kept at 39°C . Milk pH values at coagulation (6.47, 6.42, and 6.54 for Crescenza N, C, and S, resp.) were different among the trials to obtain the same curd's consistency at the moment of cutting. Curd's consistency and hardening kinetics were evaluated by means of a Formagraph instrument (Foss, Hillerød, Denmark) and by preliminary cheesemaking trials (results not shown). Because FPCC has a higher specific proteolytic activity [22] and a higher clotting strength (expressed as International Milk-Clotting Units, IMCU) if compared with calf rennet, a lower amount of coagulant was added to Crescenza C than Crescenza N and S, corresponding to 2867 IMCU/100 kg of milk and 4360 IMCU/100 kg of milk, respectively. Milk was coagulated after 11 ± 2 min from rennet addition. After curd hardening of 5 ± 1 min, cutting with “lira” and resting (25 min), the curd was kept in agitation (7.5 min) and then was separated from the whey and placed into block molds (6 molds of $6\text{ cm} \times 20\text{ cm} \times 20\text{ cm}$ cuboid shape of about 2 kg each). The molds were then placed into a warm room ($38 \pm 1^\circ\text{C}$) to continue acidification until a final pH of 5.3 was reached; after that, the cheeses were salted and cooled into brine (15% NaCl w/w) for 60 min at $13 \pm 1^\circ\text{C}$. Cheeses were then stored at 4°C in controlled humidity conditions (95%) for 6 days to complete the syneresis and the development of the cheese structure. At the end of the refrigerated storage, cheeses were portioned and packaged under modified atmosphere (N : CO_2 80 : 20). Six cheese portions were sampled from each mold and every portion was classified in function of the sampling zone referred to the cheese (Figure 1). For the usual whole shelf life period of 3 weeks, cheeses were stored at 4°C . Gross cheese chemical composition was determined using standard methods [10, 21].

2.2. Texture Analysis. A TA.XTplus Texture Analyzer (Stable Micro Systems, Godalming, Surrey, UK) equipped with a 30 kg load cell was used for all the measurements. The textural properties of Crescenza cheese were measured performing a single compression test of the sample using a stainless steel spherical probe with a 12.7 mm (0.5”) diameter (P/0.5S). To evaluate the spatial differences that could be present into Crescenza cheese, the sampling protocol illustrated in Figure 1 was applied. For symmetry, only the central portion of every cheese was used for the analysis; the portion was cut in two cheese slices that were separately analyzed. The measurements were made at 1, 3, 5, 7, and 9 cm from the center of the original cheese molds and at 1.5 and 4.5 cm from the bottom of the cheeses. A total of 20 compression tests were made for the two slices of every cheese. Moreover, to assess the effect of the storage period on the development of textural properties during shelf life, texture parameters were measured at 0, 7, 14, and 21 days of refrigerated storage. Samples were analyzed immediately after being taken out from the refrigerator. Measurements were conducted at 2 mm/s (trigger force of 5 g) until a 10 mm distance was reached; the post test speed was set at 10 mm/s. Hardness (H) and compression work (CW) were, respectively, defined as the maximum positive force and the positive work (integrated positive area) of the compression graph [1]. Adhesiveness

FIGURE 1: Sample preparation procedure for texture analysis measurements. (a) Crescenza cheese molds were portioned into six parts classified in function of the sampling zone of the cheese. (b) The central part of the mold was used for textural measurement and was cut into two slices. (c, d) The two slices were positioned with the cutting surface on the top. (e) Top view of the surface subjected to compression test, with references to cheese geometry (LF: lower face of the cheese; UF: upper face of the cheese; CP: central part of the cheese; OP: outer part of the cheese).

(Ads) was instead defined as the negative work (integrated negative area) of the graph recorded during the comeback of the probe.

2.3. Experimental Design and Statistical Analysis. The 3 different types of Crescenza cheeses were manufactured in 5 different cheesemaking days (blocking factor), with the exception of Crescenza S, that was manufactured 4 times. A split-split plot model was used to monitor the effects of formulation (C, N, and S, considered as a noncontinuous categorical variable), distance from the central point of the cheese and storage time (that were treated as continuous variables), and their interactions on textural properties. From preliminary analyses, the effect of the distance from the bottom to the top face of the cheese on textural response is not significant; thus, this variable was not taken into account in the statistical model. Cheese formulation (F_i , $i = 1, 2, 3$) was analyzed in whole-plot and cheesemaking day (B_j , $j = 1, 2, 3, 4, 5$) was used as the blocking factor. For the subplot, storage (t_k , $k = 1, 2, 3, 4$) and storage $\times$ distance from the center ($t \times d$) were analyzed. The design was then split again in order to evaluate the distance from the center (d_l , $l = 1, 2, 3, 4, 5$); formulation $\times$ storage ($F \times t$), formulation $\times$ distance ($F \times d$) and formulation $\times$ storage $\times$ distance ($F \times t \times d$) interactions were also included. The linear model used is reported in

$$Y_{ijkl} = \mu + F_i + B_j + \delta_{ij} + t_k + (t \times F)_{ik} + \gamma_{ijk} + d_l + (F \times d)_{il} + (t \times d)_{kl} + (F \times t \times d)_{ikl} + \varepsilon_{ijkl}, \quad (1)$$

where δ_{ij} , γ_{ijk} , and ε_{ijkl} were the main plot and the two subplot error terms, respectively, and Y_{ijkl} was the selected response variable. The model was built using PRC GLM of SAS (SAS Inst. Inc., Cary, NC, USA); lsmeans with LSD adjustment was used to perform multiple comparisons among means.

3. Results and Discussion

3.1. Effect of Formulation on Textural Properties. The different cheese formulations, manufactured using different rennet and starter cultures, gave similar chemical composition (Table 1), with the partial exception of a slightly lower amount of lactose and a corresponding higher amount of galactose for Crescenza S that could be due to differences in galactosidase activity between bulk and direct-to-vat starter. However, textural results were different: all textural parameters (Ha, CW, and Ads) were statistically affected by cheese formulation as reported in Table 2. Crescenza C obtained with FPCC and direct-to-vat starter culture showed the significantly highest values of Ha and CW and the lowest values of Ads. FPCC can produce a firmer cheese structure as already reported [23–25] also for Crescenza cheese and is probably related to its lower general proteolytic activity than calf chymosin [26] and to the presence of pepsin in calf rennet. On the other hand, Crescenza cheeses that were both obtained with calf rennet but with a different acidifying starter (direct-to-vat versus bulk starter composed of different biotypes of *S. thermophilus*) showed smaller differences that could be

TABLE 1: Mean composition (% w/w) of different Crescenza types manufactured for this study.

	Crescenza N	Crescenza C	Crescenza S
Fat	24.4 ± 0.6	24.0 ± 0.4	23.7 ± 0.7
Protein	14.3 ± 0.3	14.1 ± 0.3	14.4 ± 0.3
Moisture	57.1 ± 0.9	57.9 ± 0.9	57.8 ± 1.0
Lactose	1.0 ± 0.1	0.9 ± 0.1	0.7 ± 0.1
Galactose	0.7 ± 0.04	0.7 ± 0.04	0.9 ± 0.1
Acid lactic	0.8 ± 0.1	0.9 ± 0.1	0.9 ± 0.1
Sodium chloride	0.5 ± 0.1	0.5 ± 0.04	0.5 ± 0.02
Ash	1.9 ± 0.1	1.7 ± 0.2	1.9 ± 0.1
pH	5.15 ± 0.08	5.04 ± 0.05	5.04 ± 0.06

Crescenza N was manufactured using a direct-to-vat starter culture of *St. thermophilus* and calf rennet. Crescenza C was manufactured using the same direct-to-vat starter culture of *St. thermophilus* and a fermentation-produced camel chymosin (FPCC). Crescenza S was manufactured using the same calf rennet of Crescenza N and a bulk starter culture of *St. thermophilus*.

probably attributable to the different cheesemaking protocol as well as the slightly different cheese composition and pH and/or a different proteolysis of the starter bacteria. A higher effect of the type of coagulant than of the type of acidifying starter on the textural properties of Crescenza cheese is an expected result. In soft and fresh cheeses like Crescenza, the residual coagulating enzyme results as the main proteolytic factor, because of the high amount of enzyme added, the high moisture content, and the absence of a cooking process during manufacture responsible for heat denaturation; therefore, the main phenomenon that could affect the textural properties of Crescenza cheese is the casein proteolysis. In particular, cleavage of the bond Phe₂₃-Phe₂₄ of α_{s1} -Casein (CN) is the typical marker of casein proteolysis attributable to nonspecific activity of rennet [10]. As proteolysis is a time dependent phenomenon, the textural properties of Crescenza cheese were significantly influenced by storage time as a consequence. Moreover, the different formulations showed different textural trends during shelf life, as confirmed by the significant interaction formulation $\times$ storage. As said above, this fact could be due to the lower nonspecific proteolytic activity of FPCC responsible for a lower rate of hydrolysis of α_{s1} -CN in comparison with calf rennet. Moreover, also textural properties of Crescenza cheeses obtained with calf rennet (N and S) differed slightly over time. Crescenza N had higher values of Ha and CW than Crescenza S at the beginning of the storage period. During shelf life, there was an inversion of this difference, leading to higher Ha and CW values for Crescenza S than Crescenza N. From data reported in Table 3, it can be seen that Ads values presented similar increasing trend over time for all the Crescenza formulations.

3.2. Effect of Storage Time and Spatial Location into the Cheese. Temporal changes of cheese textural properties could be primarily caused by moisture losses or proteolytic phenomena; as Crescenza cheese manufactured during this study was packaged into modified atmosphere and no moisture losses were recorded during shelf life (data not shown), it can be assumed that the changes over time of texture and firmness

of the 3 cheese series were mainly caused by proteolytic phenomena. However, also a nonhomogeneous spatial distribution of moisture, renneting agents, organic acids, and salts could lead to different textural development over different locations of the cheese mold [13, 14, 18, 27]. Hypothesizing a different distribution of the coagulating agent and/or a different proteolytic activity over the geometry of the cheese caused by the modulating effect of factors such as NaCl or pH [28], the proteolytic phenomena and consequently the textural changes could be influenced both by storage and could be diversified as a function of the location into the mold [4]. It is known that Crescenza cheese may develop a structure defect during shelf life called “colatura” that leads to a flowing structure in the outer part of the cheese block where it cannot be supported by the presence of rind. However, no specific studies are known about the possible reasons of this defect that is usually caused by a too high retention of residual rennet into the cheese [5, 19] and no textural data are available. In this study, both the main effects of storage time and location (expressed as the distance from the central part of the mold) were both significant (Table 2). In particular, Ha and CW showed already at 0 d of storage a negative gradient across the distance from the central part of the block, as shown for Ha in Figures 2(a), 2(b), and 2(c). This result shows a different trend than that reported for other studies made on different cheeses, such as Cheddar, Gouda, and Camembert that are however characterized by the presence of rind [4, 15, 18, 29] and therefore by a moisture content gradient. However, as Crescenza is typically a fresh cheese without rind and with a homogeneous moisture content among cheese zones, a different spatial evolution of textural properties was not expected. The decreasing gradient of firmness from the center to the outer part of the cheese block could be probably addressed to manufacture factors (such as the influence of heat and mass flow during cooling, draining, and brining at the different locations of the cheese) that could promote the presence of a gradient thought the radial axis (e.g., NaCl, organic acids, and/or coagulants). On the contrary, Ads did not show a significant difference along the different locations of the cheese block on the 0 d of storage, except for Crescenza S and N in the outer part of the cheese block (7 and 9 cm from the center of the cheese). Ha and CW showed an initial decrease from 0 to 7 d of storage and the decrease was higher for the two Crescenza cheeses obtained with calf rennet than that obtained with FPCC; moreover, as the interaction between the distance from the center of the cheese and the storage time was significant (Table 2), the decrease of firmness of Crescenza cheese was different for the different location analyzed into the cheese block. From the 7th d of storage to the end of the shelf life period, an increase of Ha and CW in the central locations of the cheese block was measured; moreover, this increase was higher for Crescenza obtained with FPCC than that of the two Crescenza cheeses obtained with calf rennet. A similar phenomenon, not associated with the spatial location inside the cheese, was already showed in previous studies made on Crescenza cheese [30, 31]. As previously said, no moisture losses were measured during shelf life; thus, the increase of firmness could not be addressed to moisture content changes due to syneresis during shelf

TABLE 2: Effect cheese formulation (F), storage time (t), distance from the central part of the cheese (d), and their interactions on the textural properties of Crescenza cheese.

Textural parameter	df	Hardness (H)	Compression work (CW) Probabilities (P)	Adhesiveness (A)
Cheese making trial (block)	4	0.079	0.144	0.038
Formulation (F)	2	0.0020	0.0027	0.0004
Error ($F * \text{Block}$)	7			
Storage time (t)	3	<0.001	<0.001	<0.001
$F * t$	6	<0.001	<0.001	<0.001
Error ($F * t * \text{Block}$)	23			
Distance from the central part of the cheese (d)	4	<0.001	<0.001	<0.001
$F * d$	8	<0.001	<0.001	0.034
$t * d$	12	<0.001	<0.001	0.019
$F * t * d$	24	0.0027	0.001	<0.001
Error	824			
R^2		0.81	0.83	0.76
RMSE		0.24	0.63	0.04

Note. Data were analyzed as a split-split plot design using SAS procedure (SAS Institute, Cary, North Carolina). The main plot factor cheese formulation (F) was blocked using cheesemaking day as blocking factor. The design was split with storage time (t) as split-plot factor and distance from the central part of the cheese (d) as subplot factor. Statistical significance was considered at a level of $P < 0.05$.

life. As proposed by Visser [32] and also stated by other authors [33, 34], cheese can be assumed as a composite gel/filler material; the gel fraction is constituted by the casein matrix and the bounded salts (calcium phosphate) and water, while the filler fraction consists of fat, the soluble proteins (proteolysis fractions and whey proteins), unbound water, and salts in solution. The ratio of gel to filler fraction contributes to the modification of cheese firmness, as an increase in firmness during storage can be caused by the decrease of unbound water availability and consequently filler fraction. Proteolysis of casein matrix by residual rennet and microbial peptidases causes the formation of new ionic groups that can bind some of the available unbound water, reducing the filler fraction and the viscous dissipation and consequently increasing the firmness of the cheese [2, 35]. On the contrary, Ha and CW measured in the outer parts of the cheese block showed a general decrease instead of an increase from the beginning to the end of storage period, resulting in higher spatial nonhomogeneity of textural properties at 21 d instead than at 0 d. Ads values showed a general increase during the storage period; although for this parameter some differences were present in the different locations of the cheese, a clear trend was not visible.

4. Conclusions

Textural properties of 3 different Crescenza cheese formulations manufactured using different coagulating agents and starter cultures were measured during the storage period, taking into account the possible spatial nonhomogeneity of the matrix. The results showed that the textural properties of the cheese were significantly affected by all the factors considered (formulation, storage time, and location into the cheese block). In particular, also for a soft cheese with no ripening time a certain spatial nonhomogeneity of textural

properties is present; the cheeses had a firmer structure (higher Ha and CW values) in the center than in the outer part of the cheese block. Moreover, the gradient was higher at the end of the shelf life period than at the beginning, as a possible consequence of spatial differences in proteolysis' kinetics caused by gradients into the cheese geometry. This result was confirmed for all the 3 cheese formulations, although Crescenza produced with camel chymosin was slightly firmer than the Crescenza cheeses obtained with calf rennet and had a lower decrease of firmness in the outer part of the cheese during shelf life; this result is coherent with the lower general proteolysis of FPCC. The textural measurements of a fresh nonripened cheese like Crescenza cheese can be an important tool to define the quality of a product that undergoes proteolysis phenomena. Further studies including the spatial analysis of chemical properties of cheese should be carried out to better understand the kinetics responsible for the measured temporal and spatial changes in textural properties. The results of this study can help Crescenza producers to better decide the choice of ingredients in order to increase the shelf life of the cheese and to improve the knowledge about the textural properties of this cheese.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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TABLE 3: Mean values of hardness (Ha), compressive work (CW), and adhesiveness (Ads) of the series (F) of Crescenza cheese manufactured (C, N, S); results are reported as a function of storage (t) and distance from the central part of the mold (d). Calculated relative standard deviation (not shown) for reported measures was $\leq 30\%$.

F		C					N					S				
t (d)		0	7	14	21	0	7	14	21	0	7	14	21			
Ha (N)	d	1	1.77 ^{Ac}	1.65 ^{Ac}	2.17 ^{Aa}	2.08 ^{Ab}	1.49 ^{Aa}	0.85 ^{ABc}	1.14 ^{Ab}	1.27 ^{Ab}	1.09 ^{Ac}	1.33 ^{Ab}	1.60 ^{Aa}			
		3	1.75 ^{Aab}	1.61 ^{Ab}	1.88 ^{Bab}	1.97 ^{ABa}	1.50 ^{Aa}	0.86 ^{ABc}	1.10 ^{Ab}	1.22 ^{Aa}	1.02 ^{ABb}	1.36 ^{Aa}	1.40 ^{Aa}			
	(cm)	5	1.74 ^{Aa}	1.33 ^{Bb}	1.62 ^{Cab}	1.76 ^{Ba}	1.32 ^{Ba}	0.90 ^{Ab}	0.93 ^{Bb}	1.12 ^{Aa}	0.94 ^{Bb}	1.14 ^{Ba}	1.18 ^{Ba}			
		7	1.52 ^{Ba}	1.14 ^{Cb}	1.30 ^{Dab}	1.32 ^{Cab}	1.25 ^{Ba}	0.79 ^{Cb}	0.73 ^{Cb}	1.14 ^{Aa}	0.89 ^{Bab}	0.77 ^{Cb}	0.82 ^{Cab}			
		9	1.33 ^{Ba}	1.05 ^{Cb}	0.99 ^{Eb}	0.94 ^{Db}	1.19 ^{Ba}	0.69 ^{Db}	0.56 ^{Db}	1.06 ^{Aa}	0.68 ^{Cab}	0.67 ^{Db}	0.56 ^{Db}			
CW (Ns)	d	1	4.60 ^{Ab}	4.47 ^{Ab}	6.09 ^{Aa}	5.92 ^{Aa}	3.98 ^{Aa}	2.26 ^{ABc}	2.95 ^{Ab}	3.38 ^{Ab}	2.92 ^{Ac}	3.63 ^{Ab}	4.82 ^{Aa}			
		3	4.57 ^{Ab}	4.36 ^{Ab}	5.31 ^{Bab}	5.54 ^{ABa}	4.02 ^{Aa}	2.27 ^{ABc}	2.80 ^{Ab}	3.27 ^{Aa}	2.72 ^{ABb}	3.73 ^{Aa}	4.16 ^{Aa}			
	(cm)	5	4.48 ^{Aab}	3.63 ^{Bb}	4.52 ^{Cab}	4.90 ^{Ba}	3.52 ^{Ba}	2.39 ^{Ab}	2.34 ^{Bb}	3.05 ^{ABa}	2.43 ^{BCb}	3.08 ^{Ba}	3.33 ^{Ba}			
		7	3.92 ^{Ba}	3.09 ^{Cb}	3.54 ^{Dab}	3.67 ^{Cab}	3.28 ^{Ba}	2.07 ^{Bb}	1.81 ^{Cb}	1.82 ^{Cb}	3.01 ^{ABa}	2.32 ^{Cab}	2.13 ^{Cab}			
		9	3.49 ^{Ba}	2.77 ^{Cb}	2.67 ^{Eb}	2.52 ^{Cb}	3.11 ^{Ba}	1.82 ^{Cb}	1.33 ^{Db}	2.74 ^{Ba}	1.72 ^{Db}	1.42 ^{Db}	1.16 ^{Db}			
Ads (Ns)	d	1	0.09 ^{Ab}	0.17 ^{Aa}	0.19 ^{Aa}	0.21 ^{Ba}	0.13 ^{Ac}	0.18 ^{Bb}	0.27 ^{ABa}	0.15 ^{Bc}	0.21 ^{ABb}	0.20 ^{Bb}	0.30 ^{Aa}			
		3	0.09 ^{Ac}	0.17 ^{Ab}	0.18 ^{Ab}	0.27 ^{Aa}	0.13 ^{Ac}	0.20 ^{Ab}	0.30 ^{Aa}	0.15 ^{Bc}	0.23 ^{Ab}	0.23 ^{Ab}	0.29 ^{Aa}			
	(cm)	5	0.09 ^{Ac}	0.16 ^{Ab}	0.17 ^{Ab}	0.22 ^{Ba}	0.13 ^{Ac}	0.21 ^{Ab}	0.32 ^{Aa}	0.15 ^{Bb}	0.23 ^{Aa}	0.24 ^{Aa}	0.26 ^{Aa}			
		7	0.09 ^{Ac}	0.16 ^{Ab}	0.16 ^{Ab}	0.23 ^{Ba}	0.12 ^{ABd}	0.21 ^{Ac}	0.32 ^{Ab}	0.14 ^{Bb}	0.24 ^{Aa}	0.22 ^{Aa}	0.22 ^{ABa}			
		9	0.09 ^{Ad}	0.13 ^{Bc}	0.17 ^{Ab}	0.23 ^{Ba}	0.11 ^{Bc}	0.19 ^{Bb}	0.23 ^{Ba}	0.12 ^{Ab}	0.20 ^{Ba}	0.21 ^{ABa}	0.18 ^{Ba}			

Multiple comparisons were performed using GLM procedure with lsmeans option with LSD adjustment (SAS Institute, Cary, North Carolina). Means with different superscripts within each distance from the center (upper case) of the same cheese are different for each parameter considered ($P < 0.05$); means with different superscripts within each storage day (lower case) for each of the parameters measured are different ($P < 0.05$). Crescenza N was manufactured using a direct-to-vat starter culture of *St. thermophilus* and calf rennet. Crescenza C was manufactured using the same direct-to-vat starter culture of *St. thermophilus* and a fermentation-produced camel chymosin (FPCC). Crescenza S was manufactured using the same calf rennet of Crescenza N and a bulk starter culture of *St. thermophilus*.

FIGURE 2: ((a), (b), (c)) Mean values of hardness (N) of Crescenza cheese batches as a function of storage and distance from the central part of the cheese block. Crescenza C (a) was manufactured using the same direct-to-vat starter culture of *St. thermophilus* and a fermentation-produced camel chymosin (FPCC). Crescenza N (b) was manufactured using a direct-to-vat starter culture of *St. thermophilus* and calf rennet. Crescenza S was manufactured using the same calf rennet of Crescenza N and a bulk starter culture of *St. thermophilus* (c).

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