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Effect of cardoon genotype on colour and texture of Serra da Estrela Cheese

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Abstract
The objectives of this study were to evaluate the colour and the textural properties in Serra da Estrela Cheeses produced with different cardoon genotypes. The cheeses were produced with ewe´s raw milk, following the procedures adopted for the Serra da Estrela cheese with Protected Designation of Origin (PDO). The maturation time was 45 days. The results showed that lightness was very similar for the five samples evaluated (varying from 58.8 to 61.1), just like greenness (-3.2 to -2.5) and yellowness (18.8 to 20.7). Hence it was not possible to clearly identify particular colour characteristics associated with a certain cardoon genotype. However, regarding texture, the results were quite different among the cheese samples studied. Crust firmness varied from 3.9 to 5.4 N, flesh firmness from 1.0 to 1.4 N, stickiness from -2.0 to -1.1 N and adhesiveness from -15.1 to -8.3 N.s. The cardoon ecotype 1M allowed obtaining cheeses with firmer crust and flesh, while being stickier and more adhesive. As a conclusion, it was possible to verify that the genotype variability in the cardoon used for the production of Serra da Estrela cheese can in fact influence some of the product's characteristics, and particularly the texture.

Keywords
Colour Difference; Textural properties; authenticity; Cynara cardunculus

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1. Introduction

Serra da Estrela cheese is undoubtedly the most famous of the traditional cheeses from Portugal. Its manufacture process is mostly at small dairies following ancestral techniques, using only raw ewe's milk. The coagulation is achieved with flowers of wild cardoon (*Cynara cardunculus, L.*), without the addition of any animal rennet or other starter cultures [1].
The consumer's preference for raw milk cheese is continuously increasing due to its powerful and varied flavour when compared with cheese made with pasteurized milk. The development of aroma in raw milk cheeses is mainly governed by its naturally occurring microbial flora, which also contributes to the inhibition of foodborne pathogenic bacterial growth. Lactic bacteria, the dominant indigenous microorganisms of raw milk cheese, produce substances that inhibit pathogenic organisms, such as bacteria, organic acids, hydrogen peroxide, and it is possible to manufacture cheese with microbiologically desirable qualities [2].
Due to artisanal processing techniques, there is a great variability between distinct dairies, and even within the same manufacturing batch. This variability can be due to the lack of constancy of the microbiological, biochemical and physico-chemical characteristics of the milk, the chemical composition of the cardoon used and the protocols of manufacture [1].
Cheese properties are very dynamic, changing texture, colour and chemical properties during processing and maturation [3]. Texture, colour and taste are important quality parameters that govern the uniqueness of a cheese and its appreciation by the consumers. In fact, for Serra da Estrela cheese properties like texture greatly affect the preference and acceptance by the consumer, given its traditional soft paste, much valued. Cheese colour and texture are very variable along the ripening process [3] and depend on several different factors, including the type of milk, the processing operations and maturation conditions [4].
Given the importance of the coagulant used in this type of cheese, the objectives of this work were to evaluate the variability in the colour and textural properties of Serra da Estrela cheese as induced by different cardoon flower genotypes. One goal would be to possibly identify which genotype(s) would better adjust to obtain cheeses with most desired qualities.

2. Experimental Procedure

2.1. Cheese samples

The milk and cheeses used in this study are from the demarcated region of Serra da Estrela cheese, more precisely in the municipality of Penalva do Castelo. The milk used came from the milking of the herd of Casa da Ínsua, exclusively of Serra da Estrela sheep. The production of cheeses and maturation process was done at Casa das Ínsua dairy, during the period between March and April 2016. The maturation time of the chesees studied was 45 days.
The cardoon samples of different genotypes used in this work were 1M, 3M, 5M, 5MA and 6M, and they all came from a small test field located in Viseu (40º42'17.5"N; 7º54'45.8"W), whose flowers were harvested and dried in July 2015.

2.2. Evaluation of colour

The colour was evaluated using a hand tristimulus colorimeter (Chroma Meter - CR-400, Konica Minolta) which was calibrated with a white standard tile. The CIE standard illuminant D65 was used to assess the CIELab colour space coordinates, L*a*b* values. This system is suggested by Mendoza et al. [5] as the most suitable colour space for quantification in foods with curved surfaces. The coordinates measured were the lightness L*, which varies from 0 to 100 (corresponding respectively to black and white), and the coordinates of opposed colour: a* and b*, which vary from –60 to +60, where the a* assumes negative values for green and

positive values for red, while b* assumes negative values for blue and positive for yellow [6]-[8]. In each cheese 15 measurements were made in different parts of the crust, to calculate the mean value and standard deviation.
The Cartesian coordinates can be used to calculate the polar or cylindrical coordinates: VH°C, with V representing the value, H° the hue angle and C the chroma, as defined by equations (1) to (3):

$$V = \frac{L^*}{10} \tag{1}$$

$$\begin{cases} H^o = arctg\ (b^*/\ a^*),\ for\ a^*>0\ ;\ b^*>0 \\ H^o = 180^o + arctg\ (b^*/\ a^*),\ for\ a^*<0\ ;\ b^*>0 \\ H^o = 270^o + arctg\ (b^*/\ a^*),\ for\ a^*<0\ ;\ b^*<0 \\ H^o = 360^o + arctg\ (b^*/\ a^*),\ for\ a^*>0\ ;\ b^*<0 \end{cases} \tag{2}$$

$$C = \sqrt{a^{*2} + b^{*2}} \tag{3}$$

2.3. Analysis of texture

To evaluate the textural characteristics, perforation tests were carried out using a Texture Analyser (model TA.XT.Plus, Stable Micro Systems). In each cheese 3 measurements were made in the bottom and in the top faces, to calculate the mean value and standard deviation. The test performed was measure force under puncture with a probe P/2 (2mm diameter). The operational parameters were: pre-test speed = 2.00 mm/s, test speed = 1.00 mm/s and post-test speed = 1.00 mm/s, distance = 10.0 mm, trigger force = 0.029 N, load cell = 50 kg. The curve force (N) versus time (s) (Figure 1) allows calculating the crust firmness, the inner firmness and adhesiveness, according to equations (4) to (7):

Crust firmness (N) = Fe *(maximum force)* (4)
Inner firmness (N) = Fi *(average force between lines 1 and 2)* (5)
Adhesiveness (N.s) = A *(negative area - marked green)* (6)
Stickiness (N) = Fn *(minimum force - negative)* (7)

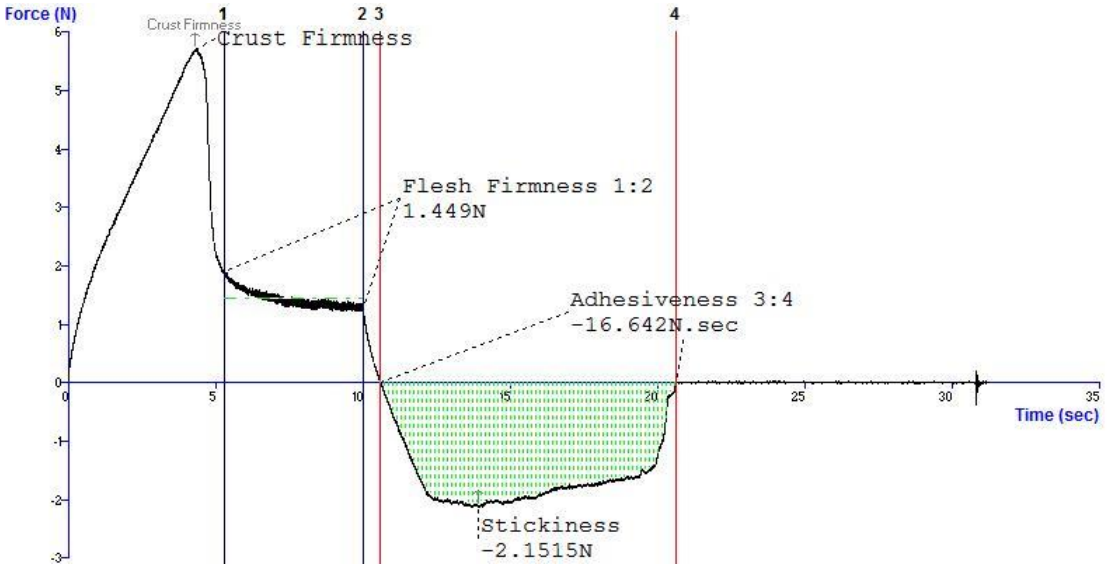

Figure 1. Texture perforation test curve.

3. Results and Discussion

3.1. Colour properties

The graph in Figure 2 shows the values of lightness (L*) for all samples evaluated, which ranged from 58.8 for sample 3M to 61.1 for sample 1M, being this last the clearest of all cheese samples evaluated (higher value). These values of L* varied in a narrow range, thus being all samples quite homogeneous in terms of lightness. Correia et al. [9] reported values of lightness for Serra da Estrela Cheese varying in a wider range, from ~60 to ~90, for similar ripening periods. Also Correia et al. [10] reported values of L* for Serra da Estrela Cheese varying from 59.5 to 63.4, thus lower than in the present study, but that might be because the maturation time was only 30 days instead of 45 used in this work.

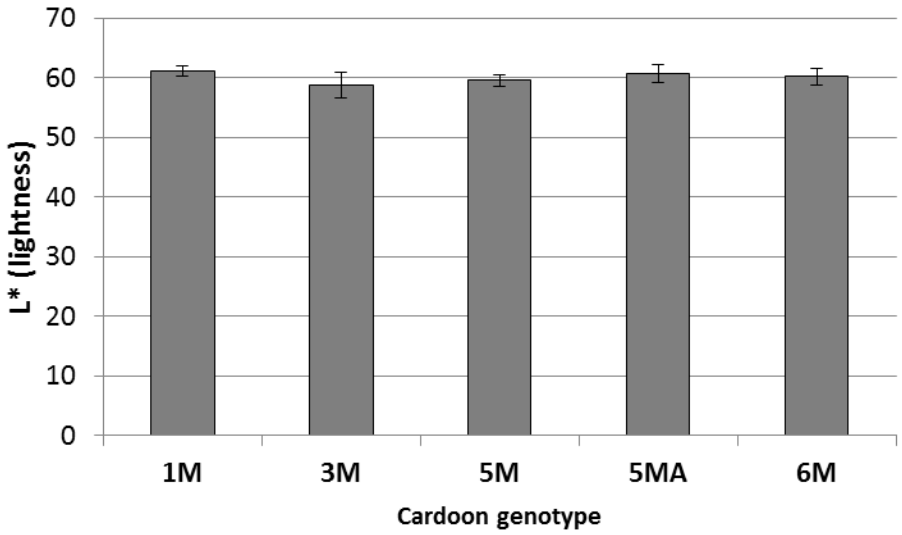

Figure 2. Colour coordinate L* evaluated in the cheeses produced with different cardoon genotypes.

Figure 3 presents the values of the colour coordinate a* for the cheese samples analysed. These values are negative in all cases, thus indicating that the predominant colour is green instead of red, which would be for positive values of a*. Nevertheless they are very close to zero, indicating that the green colouration is very weak.

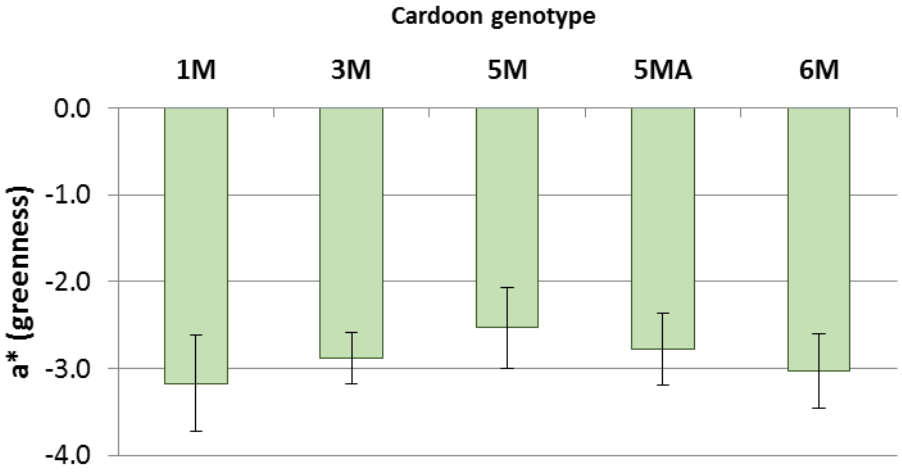

Figure 3. Colour coordinate a* evaluated in the cheeses produced with different cardoon genotypes.

The values of a* varied from -3.2 for sample 1M, which was the one with highest intensity of green, to -2.5 for sample 5M. The values reported by Correia et al. [9] for the same type of cheese with similar maturation times were from approximately -4.5 to -1.5, and those by Correia et al. [10] for slightly less ripe cheese were from -3.4 to -1.6, which are in both cases similar to the values found in this work.
The graph shown in Figure 4 relates to the values of the coordinate b*, which is always positive, so corresponding to the predominance of a yellow coloration instead of blue (which would be for negative values of b*). The evaluated samples had values of b* ranging from 18.8 to 20.7, indicating that the yellow colour is intense. Also it is possible to verify that the variability among samples was not much evident. Correia et al. [9] for Serra da Estrela cheese with similar maturation times found values from approximately 15 to 35, being a much wider range. In the work by Correia et al. [10] for slightly less ripe cheese were reported values of b* varying from 31.0 to 33.5, which are considerably higher and therefore corresponding to cheeses with a more intense yellow coloration. Carocho et al. [11] reported a value of yellowness for Serra da Estrela Cheese of ~26, which is similar to those found in this work.

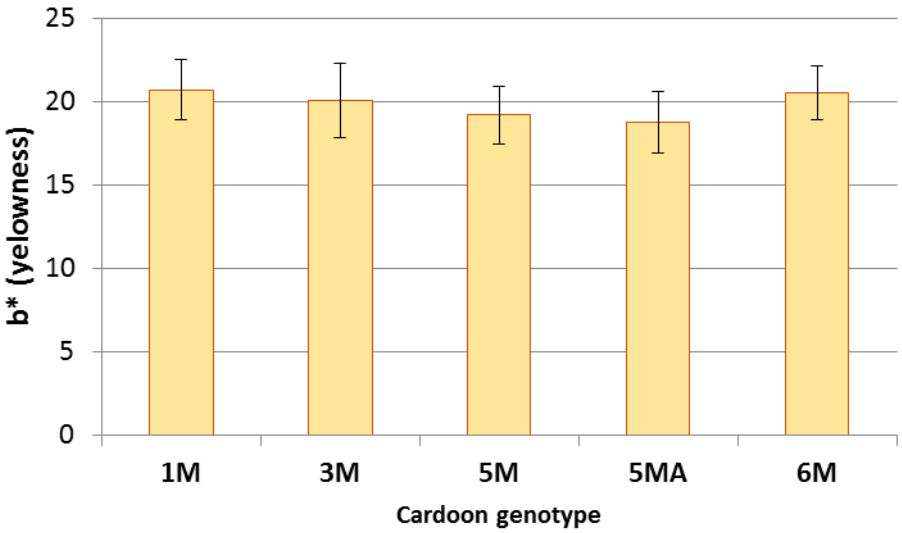

Figure 4. Colour coordinate b* evaluated in the cheeses produced with different cardoon genotypes.

Table 1 shows the results calculated for value, chroma and Hue angle, for all the samples evaluated. Higher values of chroma indicate higher purity of colour, while lowest values (close to zero) correspond to more faint colours.

Table 1. Cylindrical colour coordinates calculated for the cheeses produced with different cardoon genotypes.

Cardoon genotype	Value (V)	Chroma (C)	Hue angle (Hº)
1M	6.11	20.97	179.85
3M	5.88	20.27	179.86
5M	5.96	19.37	179.87
5MA	6.07	18.96	179.85
6M	6.03	20.75	179.85

The values obtained for chroma ranged from 19.4 to 21.0, thus indicating pure colours. The hue angle was practically equal for all samples (179.9), thus indicating the same tonality. For values of hue near 0ºC or 360ºC the tone is red, while for hue angles around 180º the tone is

green, which is the present case. The results obtained for hue are, therefore, in accordance with those seen for a*, i.e., the samples being in green spectrum.

3.1. Textural properties

The crust firmness relates to the resistance of the cheese rind to the probe under penetration, and is a measure of its hardness. Figure 5 shows the values obtained for the crust firmness in both faces of the cheeses evaluated (top and bottom), as well as the whole cheese (considering the average between the measurements made in the whole sample). During ripening it is supposed to turn the cheeses very frequently to produce uniform characteristics on both faces. However, the present results show that for all samples, there was a very distinct difference between the top and bottom faces of the cheeses. In all cases the top face was the hardest, thus being more dehydrated and therefore corresponding probably to more time turned up when compared to the bottom face. When comparing the results obtained for the whole (global) cheeses, the sample 1M showed a higher crust firmness (around 5 N) while the samples 5M, 5Ma and 6M presented the lowest crust firmness (around 4 N). Correia et al. [10] reported values of crust firmness varying from 2.4 to 5.6 N for Serra da Estrela Cheese with 90 days of maturation.

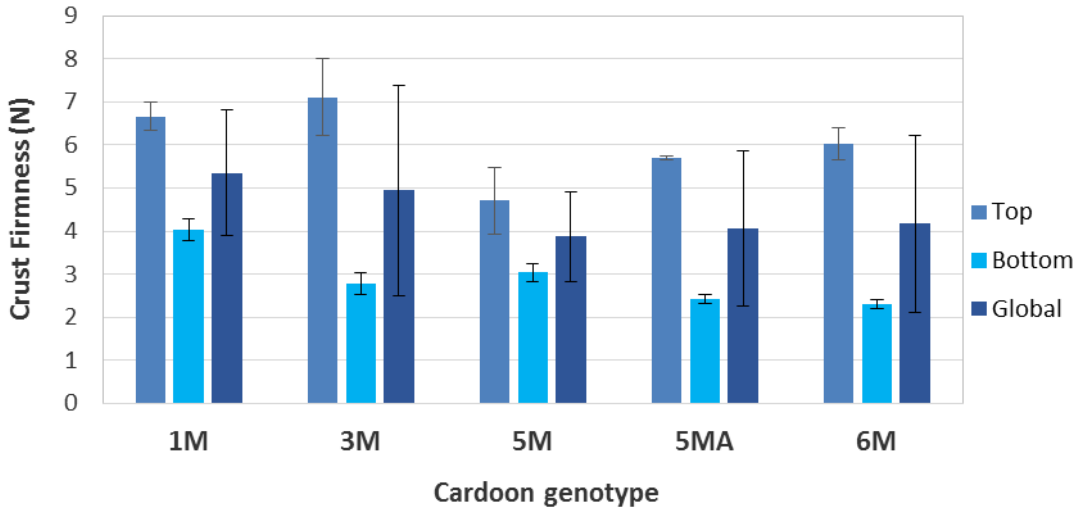

Figure 5. Crust firmness of the cheeses produced with different cardoon genotypes.

The flesh firmness is linked to the resistance of the cheese core to the probe under penetration, and is a measure of the softness of the paste. Serra da Estrela cheese is a soft and spreading paste cheese, so the values of the inner firmness are expected to be quite low. Figure 6 reveals the values of flesh firmness obtained for the samples evaluated, and the trend is similar to that observed for the crust firmness, i.e., a clear asymmetry between the two faces of the cheeses. The values, considering the whole cheese, ranged from 1.0 to 1.4 N, thus corresponding to much lower values when compared with the crust firmness. Also Correia et al. [10] reported values of inner firmness varying from 0.8 to 1.8 N for Serra da Estrela Cheese with 90 days of maturation, which are very similar to those encountered in this work.

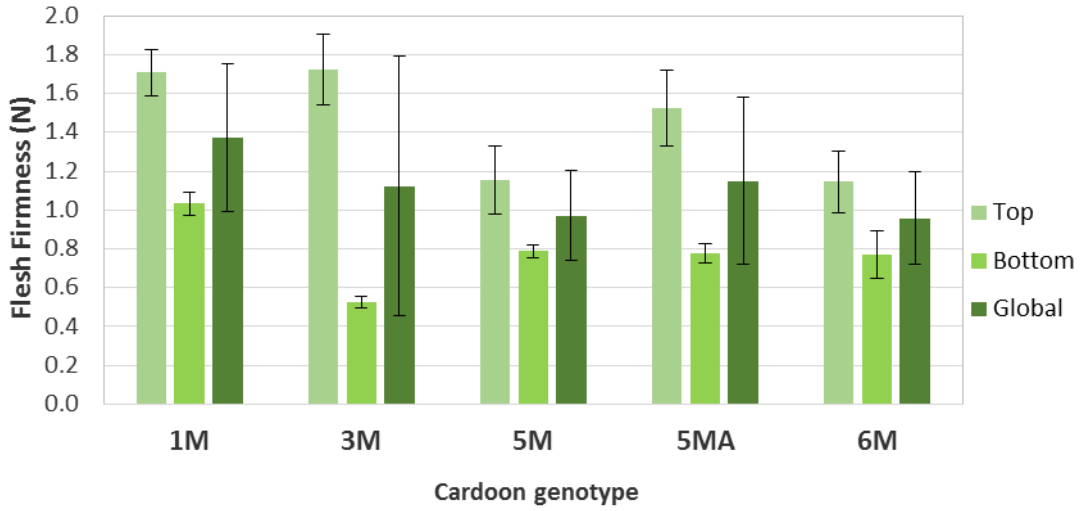

Figure 6. Flesh firmness of the cheeses produced with different cardoon genotypes.

Stickiness refers to the minimum force corresponding to the deepest point of penetration, when the probe starts to return to the initial position. Figure 7 shows that stickiness was following a similar trend as previously seen for the other textural properties, with all samples being considerably non-homogeneous in terms of top or bottom faces. The values obtained for the whole cheese varied from -2.0 to -1.1, being similar to those reported by Correia et al. [10], which were from -0.5 to -1.6. Stickiness was higher (lower negative values) for the cheese samples produced with the cardoon genotypes 1M and 3M.

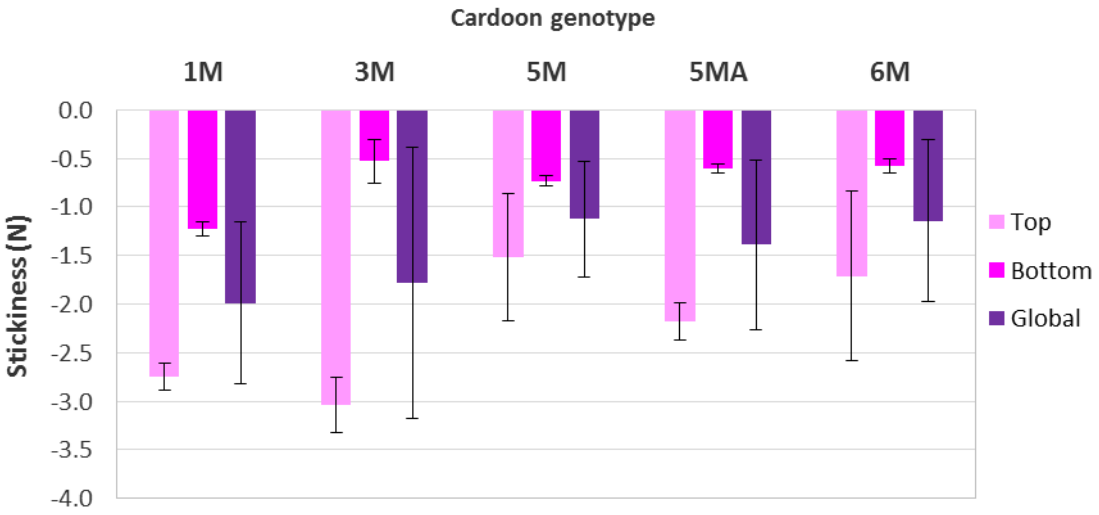

Figure 7. Stickiness of the cheeses produced with different cardoon genotypes.

Adhesiveness is the force required to remove the material that adheres to the surface of the probe. Figure 8 reveals the values of adhesiveness obtained for the cheese samples studied. The values varied from -15.1 to -8.3 N.s, being slightly different from those found by Correia et al. [10], -11.3 to -3.0. Thus, the present samples corresponded to cheeses with more spreadable characteristics as compared to those analysed by Correia et al. [10]. Like previously seen for stickiness, adhesiveness was higher (lower negative values) for the cheese samples produced with the cardoon genotypes 1M and 3M, being these genotypes the ones that allowed obtaining a product with a more spreadable paste, which is for many consumers a quality indicator for this type of cheese, although it is also much appreciated with a more firm structure.

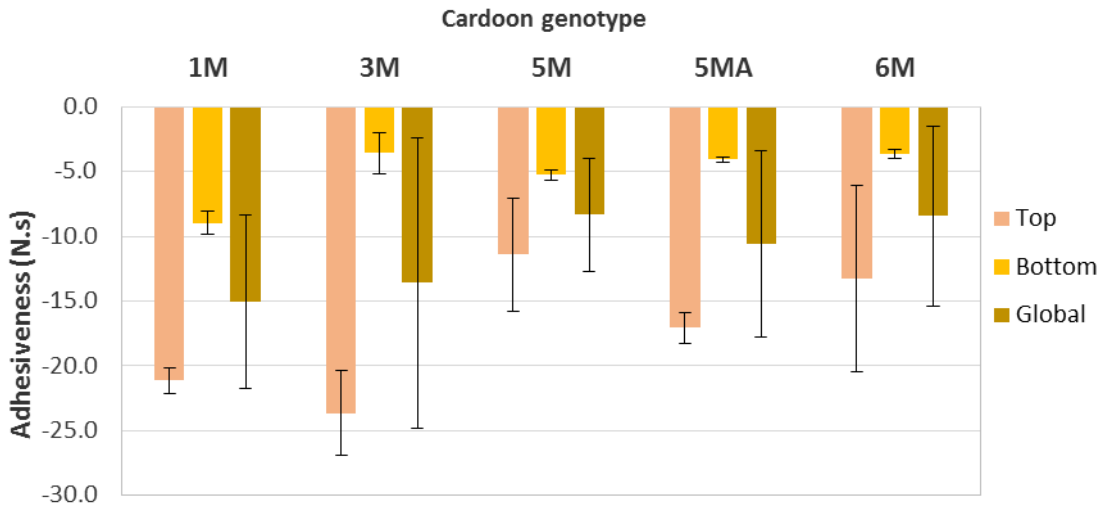

Figure 8. Adhesiveness of the cheeses produced with different cardoon genotypes.

4. Conclusions

Relatively to colour, the results obtained did not allow to clearly differentiating the cheeses as a function of the cardoon genotype used for its production. Hence, it is not possible to identify which possible genotype would allow obtaining some particular characteristics of the cheese, for the results were quite similar either for the Cartesian or the cylindrical colour coordinates.
With regards to texture, the results clearly showed that the cardoon genotype influenced the textural characteristics of the cheese, with genotype 1M allowing obtaining cheeses with firmer crust and flesh, while being stickier and more adhesive.
The results obtained in this work allowed concluding that the genotype variability in the cardoon used for the production of Serra da Estrela cheese can in fact influence some of the product's characteristics, and hence could be used as a way to obtain certain characteristics, as specified in function of product acceptability and valorisation.

6. References

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