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Usefulness of a large field of view sensor for physicochemical, textural, and yield predictions under industrial goat cheese (Murcia al Vino) manufacturing conditions

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ABSTRACT

The applicability of a light backscatter sensor with a large field of view was tested for on-line monitoring of coagulation and syneresis in a goat cheese (Murcia al Vino) manufactured under industrial conditions. Cheesemaking was carried out concurrently in a 12-L pilot vat and a 10,000-L industrial vat following the normal cheesemaking protocol. Cheese moisture, whey fat content, hardness, springiness, and adhesiveness were measured during syneresis. The results obtained show that cutting time is best predicted by considering the coagulation ratio at the inflection point and the percentage increase in the ratio during coagulation, with no need for the first derivative. The large field of view reflectance ratio provided good results for the prediction of moisture content, yield, hardness, springiness, and adhesiveness of the final cheese.
Key words: moisture, yield, cutting time, sensor

INTRODUCTION

Predictions of cutting time, moisture, and cheese yield are useful for adjusting technological procedures during cheesemaking and are therefore considered an appropriate tool for ensuring high-quality products and profitability. Formaggioni et al. (2008) reviewed the different predictive formulas proposed in the literature for calculating cheese yield, and Emmons et al. (1990) described the various predictive formulas of cheese moisture in the literature and developed new formulas, using an approach based on theoretical considerations concerning the distribution of solids and moisture in the different phases but under experimental conditions (Formaggioni et al., 2008).

Cutting time, moisture content, and cheese yield have been predicted by means of optical sensors, such as the CoAguLite fiber optic sensor (Reflectronics Inc., Lexington, KY) developed by Payne et al. (1997). The CoAguLite sensor is not only able to predict cheesemaking indices, such as cutting time and cheese yield, but it can also be used to develop algorithms of curd moisture and fat loss during milk coagulation. The sensor has been used to study (1) the effects of temperature, inocula, and $CaCl_2$ concentrations in experimental conditions without applying all the manufacturing processing steps (Castillo et al., 2000, 2002, 2003); (2) a possible application during cheesemaking until cutting time; and (3) the ability to predict cheese yield, moisture, and fat contents in cow milk and under experimental conditions without applying all the processing steps involved in cheese production (Fagan et al., 2007d, 2008). Nevertheless, this sensor showed low applicability for predicting the above parameters after curd cutting. To improve the results observed, a light backscatter sensor with a large field of view (**LFV**) was developed as a prototype model and tested in experimental conditions using different milk protein and fat contents, firmness and protein ratio levels, and stirring speeds (Fagan et al., 2007b,c,d; Mateo et al., 2010). Its ability to predict whey production and fat content in whey at syneresis was confirmed, with the results being better than those obtained with the CoAguLite sensor. The same authors highlighted the importance of testing the LFV sensor under industrial conditions, following the processing steps involved in cheese manufacturing.

The LFV sensor has been used in different experimental designs. Until now, the factorial experimental designs carried out include 3 gel-cutting intensities, 3 curd-stirring speeds, 2 protein levels and fat:protein ratios, 4 milk fat levels, and, finally, 3 firmness levels, all using recombined milk (skim milk powder and distilled water) but not pasteurized cow or goat milk, as is used in industrial cheese manufacture. In each of those

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LFV sensor application experiments, stirring continued during syneresis, without taking into account the contribution of individual steps in the overall process, such as the pitching, washing, and cooking processes, which take place in many industrial manufacturing processes and that have a great effect on final cheese properties and yield (Mateo et al., 2010). In addition, different cutting programs have been tested for the application of this sensor in recombined milk (12% TS; Mateo et al., 2009) without considering the variations involved in day-to-day production.

Only one study was found regarding the application of the LFV sensor that took into account the manufacturing processes involved in a common goat cheese variety. Rovira et al. (2011) applied the prototype LFV sensor for the on-line monitoring of fresh goat cheese during its manufacture on an experimental scale. These authors used the CoAguLite sensor as a reference to select suitable configuration details for the LFV sensor for this type of cheese and manufacturing design, finding the appropriate wavelengths to be 990, 1,000, and 1,010 nm.

Unavoidable day-to-day variations are of great importance for the application of any prediction algorithm derived from the sensor and should be taken into account if the obtained results are to be directly transferred to industrial conditions. All preliminary prediction algorithms so far developed with the LFV sensor include sensor parameters that are difficult to measure in industrial conditions and by cheese makers in general.

The aim of this work was to apply the LFV prototype sensor under industrial processing conditions to a washed pressed goat cheese (Murcia al Vino), developing new algorithms for the prediction of cutting time, moisture, and cheese yield. Such a study is a necessary step if the LFV sensor is to be useful on an industrial scale.

MATERIALS AND METHODS

Milk Source and Compositional Analysis

The goat milk for cheese making was pasteurized in the Central Quesera Montesinos S.L (Murcia, Spain) dairy at 74.5°C for 15 to 20 s and was used immediately. The average values of milk composition (as analyzed by the suppliers) are shown in Table 1.

Cheesemaking Procedure

On 13 randomly chosen days, Murcia al Vino (a washed-curd, semihard, pressed cheese, with a cylindrical shape and a smooth rind; washed in red wine and ripened for 45 d) goat cheeses weighing 500 g and 2 kg were manufactured in parallel at 2 different levels: in a 10,000-L vat in the Central Quesera Montesinos S.L. dairy following existing standards concerning the manufacture of Protected Designation of Origin Murcia al Vino cheese, and in a 12-L pilot scale vat (Pierre Guerin Ibérica S.A., Burgos, Spain), respectively, following the same processing steps and using the same raw materials. The average values of cheese composition are shown in Table 1.

All steps carried out were those followed for Murcia al Vino cheese manufacture. Calcium chloride (Betelgeux, S. L., Gandía, Valencia, Spain) and starter were added to the milk. When the milk reached 33.3°C, rennet (50L NG Reniplus, Caglio Star España S.A., Murcia, Spain) was added at 0.026 mg/L.

The curd was cut (for 6 s) and pitched (for 5 min) 40 min after adding the rennet. A second cut lasting 10 min was carried out, followed by 2 series of pitchings (5 min) and stirrings (10 min). The next step corresponded to draining (15% of the initial amount of milk), before washing and heating the curd at 38°C in a simultaneous process that lasted 25 to 30 min (with an approximate temperature increase of 1°C every 5 min). After heating, a series of stirring (10 min) and pitching (5 min) steps was carried out for 1 h until the pH decreased to 6.3. The curd was then molded, pressed for 2 h, and introduced into a brine bath for 1 d and left to mature under controlled temperature and humidity conditions for 45 d. Cheeses were immersed in red wine after 30 d of ripening and left to ripen for another 15 d.

On-Line Light Backscatter Monitoring Instrumentation

Two sensors were coupled to the 12-L air-conditioned vat: the CoAguLite sensor (model 5, Reflectronics Inc.;

Table 1. Physicochemical composition of milk and cheese

Parameter	Mean ± SD
Milk	
Protein (g/100 mL)	3.46 ± 0.05
Fat (g/100 mL)	4.76 ± 0.22
DM (g/100 g)	13.30 ± 0.02
pH	6.77 ± 0.01
Acidity (° Dornic)	13.96 ± 0.33
Cheese	
Protein (g/100 g)	23.52 ± 0.97
DM (g/100 g)	65.74 ± 1.30
Fat (g/100 g)	39.12 ± 1.70
pH	5.25 ± 0.10
Hardness (N)	26.34 ± 4.66
Springiness (mm)	7.31 ± 1.12
Adhesiveness (N·s)	1.84 ± 0.81
Cheese yield (L/kg)	7.50 ± 0.17