J. Dairy Sci. 97:2567–2577
http://dx.doi.org/10.3168/jds.2013-7522

Lactose and galactose content in cheese results in overestimation of moisture by vacuum oven and microwave methods

H. Lee,* S. A. Rankin,*[1] L. M. Fonseca,† and F. X. Milani*
*Department of Food Science, University of Wisconsin, Madison 53706
†Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES) and School of Veterinary Medicine, Universidade Federal de Minas Gerais, Belo Horizonte-MG 31270-901, Brazil

ABSTRACT

Moisture determination in cheese is a critical test for regulatory compliance, functionality, and economic reasons. Common methods for moisture determination in cheese rely upon the thermal volatilization of water from cheese and calculation of moisture content based on the resulting loss of mass. Residual sugars, such as lactose and galactose, are commonly present in cheeses at levels ranging from trace amounts to 5%. These sugars are capable of reacting with other compounds in cheese, especially under the thermal conditions required for moisture determination, to yield volatile reaction products. The hypothesis of this work is that residual sugars in cheese will be converted into volatile compounds over the course of moisture determination at a level sufficient to result in overestimated cheese moisture. A full-factorial statistical design was used to evaluate the effects of cheese type, sugar type, sugar level, method type, and all interactions. Cheddar and low-moisture, part-skim (LMPS) Mozzarella cheeses were prepared with 1, 3, and 5% added lactose or galactose, and subjected to either vacuum oven or microwave-based moisture determination methods. Browning index and colorimetry were measured to characterize the color and extent of browning. Volatile analyses were performed to provide chemical evidence of the reactions proposed. The presence of residual sugars altered moisture calculations as a function of cheese type, sugar type, sugar level, method type, and numerous interactions. At higher concentrations of residual sugar, the percentage moisture determinations were increased by values of up to 1.8. Measures of browning reactions, including browning index, colorimetry, and volatile profiles demonstrate that the proposed browning reactions played a causative role. This work establishes the need to consider cheese type, sugar type, sugar levels, and method type as a means of more accurately determining moisture levels.

Key words: moisture, lactose, cheese

INTRODUCTION

Moisture in cheese is important from the regulatory, functional, and economic viewpoints. Accurate and precise measurement of cheese moisture is especially important to maximize yield and achieve economic parity. Standard methods for determining moisture involve volatilization of available water through the application of heat and vacuum (AOAC, 1990). Because cheese is a chemically complex and variable medium, composition-dependent volatiles may be created during this analysis. As these methods calculate moisture based on the relative loss of mass from drying, such volatiles, if created and volatilized in sufficient mass, would result in a moisture overestimation. For instance, composition-dependent volatiles may be created from residual sugars in cheese reacting with nitrogenous substrate through various browning reaction pathways.

Volatile compounds may be created during heating through various chemical reactions, such as Maillard browning (Hodge, 1953). The first stage of Maillard browning involves the condensation of a reducing sugar and an amino group to form an Amadori rearrangement product (**ARP**). Further reactions of ARP take place via 1,2/2,3-enolization or Strecker degradation. Low pH values are known to favor the formation of 5-hydroxymethyl-2-furaldehyde (HMF) via 1,2-enolization, whereas reductones, decomposition products, and Strecker aldehydes are preferred at a neutral or higher pH via 2,3-enolization or Strecker degradation.

Maillard browning between lactose and amines can result in the formation of lactones, aldehydes, furans, alcohols, acids, and sulfur-containing compounds (Ferretti and Flanagan, 1971). A generalized Maillard browning scheme under neutral pH may form maltol (Labuza, 1994) or Strecker degradation products such as Strecker aldehydes (Hodge, 1953). The amount of residual sugar in cheese may be up to 5% of the total

Received September 24, 2013.
Accepted January 26, 2014.
[1]Corresponding author: sarankin@wisc.edu

mass, depending on the variety of cheese and extent of fermentation. Quantitatively, 1 mol of lactose reacted with equimolar lysine can yield up to 1 mol of maltol and 2 mol of water. Thus, 5 g of lactose in 100 g of cheese may result in the generation of up to 1.84 g of maltol and 0.53 g of additional water. These reaction products, if completely volatilized, would result in a 2.37 g of additional loss of mass and an overestimation of moisture.

It is hypothesized that sufficient volatiles will be created during drying as a function of sugar type and level, thus overestimating the moisture content of cheese. The objective of this study was to examine the effects of varying levels of residual lactose and galactose on moisture determination using vacuum oven or microwave-based analyses. Additionally, volatile profiles were examined as a means of validating the conversion of cheese-based reactants into volatile browning reaction products.

MATERIALS AND METHODS

Cheese Preparation

Cheddar cheese was manufactured at the University of Wisconsin-Madison dairy processing plant, and commercial low-moisture, part-skim (**LMPS**) Mozzarella cheese was obtained from a retail store. Cheese samples were kept refrigerated (4°C) until needed and were used within 1 mo of manufacture. The compositions of Cheddar and Mozzarella cheeses are listed in Table 1. Cheese samples were cut into uniform 1-cm cubes using a cheese cuber (Nemco N55300A; Nemco Inc., Hicksville, OH) and blended (approximately 12,000 rpm) for 15 s (model No. 430; Oster John Manufacturing Company, Milwaukee, WI). Samples of α-lactose monohydrate (Fisher Scientific, Fair Lawn, NJ) and galactose (Acros Organics, Geel, Belgium) were dried in a desiccator for 24 h and then added to cheese as the reducing sugar treatments at levels of 0, 1, 3, and 5% as a total weight of the final experimental unit. Before analysis, blended cheeses were held for 24 h at 4°C. The entire experiment was replicated 3 times.

Vacuum Oven Moisture Analysis

In accordance with a published method for moisture determination (Wehr and Frank, 2004), aluminum dishes (20 mL, 4.4 cm i.d; Fisher Scientific, Pittsburgh, PA) and fiberglass covers (4.4 cm i.d; Fisher Scientific) were dried in a vacuum oven (model no. 3623; Lab-Line Instruments Inc., Melrose Park, IL) for 1 h at 100°C. Each cheese sample (3 g) was weighed into an aluminum dish on an analytical balance. After the dish was covered with a filter paper, samples were placed in the vacuum oven for 5 h at 100°C, and vacuum (98 mmHg) was applied (Cenco model 91506 vacuum pump; Central Scientific Company, Chicago, IL). The samples were cooled in a desiccator to room temperature before weighing.

Microwave Moisture Analyzer Moisture Analysis

Moisture was determined in parallel to the vacuum oven method using a microwave moisture analyzer (CEM Smart System 5; CEM Corp., Matthews, NC). Fiberglass square sample pads (10 cm; CEM Corp.) were dried for 1 h at 100°C in an oven, and then kept in a desiccator until needed. Cheese samples (2 g) were evenly distributed between the sample pads, and then placed in the internal balance of the microwave moisture analyzer. Each sample was heated for 2 min at the highest power setting.

Moisture Calculation

The moisture content was calculated by weight difference after drying. Overestimated moisture (**OEM**) was calculated as the difference between the percentage moisture of the treated and control samples:

$$\text{OEM} = \%\text{ moisture (treatment)} - \%\text{ moisture (control)}.$$

Browning Index and Colorimetry

The browning index (**BI**) was determined after moisture analysis using the following method (Palombo et

Table 1. Composition (%; n = 2) of Cheddar and low-moisture, part-skim (LMPS) Mozzarella cheese for moisture analysis

	Cheddar		LMPS Mozzarella	
Item[1]	Mean	SD	Mean	SD
Moisture	36.7	0.06	47.1	0.04
Fat	31.8	0.05	20.8	0.09
Protein	25.9	0.02	26.5	0.03
Ash	4.03	0.02	3.69	0.05
Lactose	0.1	0	<0.1	0
Galactose	ND[2]	ND	ND	ND
pH	5.17	0	5.13	0
NaCl	1.76	0.01	1.74	0.02

[1]Moisture determined by vacuum oven method (Wehr and Frank, 2004); fat by Mojonnier method (Min and Boff, 2003); protein by Kjeldahl method (Chang, 2003); ash by combustion method (Harbers and Nielsen, 2003); lactose and galactose by HPLC method (BeMiller, 2003); pH by quinhydrone golf electrode method (Sadler and Murphy, 2003); and NaCl by direct titration method (Carpenter and Hendricks, 2003).

[2]Not detected.