MONITORING THE MILK ACIDIFICATION BY THE CONDUCTOMETRIC METHOD

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Abstract

Milk has conductive properties because it contains charged compounds, especially mineral salts. The determination of the electric conductivity of individual milk components allowed the identification of individual contributions to overall conductivity. The addition of NaCl to milk caused an increase in conductivity that was only 77.78% of that in aqueous solutions, due to the equilibrium between soluble and colloidal salts, and other soluble substances, which interfere with the salts and decrease its conducting power. Milk acidification and the decrease of pH are due to the lactose fermentation when lactic acid is formed. The phosphoric acid, the citric acid, and their acid salts have a buffering role in milk, so that the incipient milk acidification is at first buffered. Lactic acid added to fresh milk decreased the pH and increased the electrical conductivity of milk. The increase in electric conductivity for addition of lactic acid to raw milk is from 5.2 mS/cm to 5.7 mS/cm, and for addition of lactic acid to deionized water is from 0 mS/cm to 0.56 mS/cm. We observed that when the same quantity of lactic acid is added to milk the curve for electrical conductivity increase is parallel to that of aqueous solutions, but with lower absolute values. The lower incrementally increase in conductivity is due to the uptake of protons by the buffers present in milk. HPO_4^{2-} changes into $H_2PO_4^-$ as pH decreases, which has a lower molar conductivity. The variation of the electrical conductivity incrementally with variation of lactic acid concentration makes possible the use of this biophysical parameter for monitoring milk acidification.

Key words: pH, electric conductivity, lactose, milk, lactic acid

INTRODUCTION

Milk has conductive properties because it contains charged compounds, especially mineral salts. The electrical conductivity of milk is determined primarily by sodium and chloride ions but also by other ions [2].

Particularly important is the distribution of salt fractions between soluble and colloidal forms [5]. Such distribution depends on an equilibrium modified by pH and temperature changes in milk [3]. The acidification and cooling increase the soluble salts. Basic and acidic free amino acids are conductors. The contribution of milk proteins to overall conductivity is difficult to quantify but it is assumed to be small, considering their molecular size. Lactose, an uncharged sugar, cannot conduct electrical current. Fat is a nonconductor and hinders the conduction of electricity by occupying volume and by impeding the mobility of ions. Lactic acid and short-chain free fatty acids, which can be good conductors, are negligible in fresh milk [4]. Reports of studies on conductivity changes associated with fat metabolism apparently do not exist.

MATERIALS AND METHODS

The electrical conductivity (σ) was measured with the conductivity meter type OK-102/1 (Radelkis). The instrument was standardized with KCl solutions of known conductivity before use. The cell was washed with 0.01 M KCl followed by two rinses with the sample prior to measurement. Temperature corrections were made, as the samples were not analyzed at 25°C. The pH of the solutions was determined using a digital pH-meter.

The following solutions were prepared using analytical grade reagents: 5000 mg/100mL of lactose, 30 mg/100mL of urea, and 100 mg/100 mL of NaCl, KC1, sodium lactate, sodium citrate, and K_2HP0_4. A solution containing 10% (wt/wt) lactic acid was prepared, and 0.2 mL of this solution was progressively added to milk and deionized water. After each addition of lactic acid, electrical conductivity and pH were determined.

The biochemical and biophysical parameters were assayed with the standardized analytical methods [1].

The determination of the conductivity of individual milk components allowed identification of individual contributions to overall conductivity.

RESULTS AND DISCUSSION

The role of milk components was confirmed by conductivity measurements on pure solutions of the components present in milk (Table 1).

Table 1.
Electrical conductivity of milk, milk fractions and components

Component	Concentration mg%	Electrical conductivity mS/cm
Raw milk		5.22
Milk after 48 hours		5.80
Milk + NaCl	100	1.26
Milk + Sodium lactate	100	0.40
Lactose	5000	0.02
Urea	30	0.003
KCl	100	1.64
NaCl	100	1.62
K_2HPO_4	100	1.20
Sodium citrate	100	0.85
Sodium lactate	100	0.52

A combination of conductivities of the salt solutions yielded a conductivity that was higher than that of milk because this combination represented only the rough composition of the salt fraction of milk, because in milk it's a equilibrium between soluble and colloidal salts and the mineral fraction of milk contains also other soluble substances, which interfere with the salts, and therefore decrease its conducting power. For example, addition of NaCl to milk caused an increase in conductivity that was 77.78% of that in aqueous solutions. Also, the increase in conductivity caused by addition to milk of sodium lactate was 76.92% of that in aqueous solutions (Table 1).

The pH decreased from 6.48 to 5 when lactic acid was added to fresh milk. The electric conductivity increase for addition of lactic acid to raw milk is from 5.2 mS/cm to 5.7 mS/cm, and for addition of lactic acid to deionized water is from 0 mS/cm to 0.56 mS/cm. Lactic acid and its salts are important conductors. Although these molecules are present in small amounts in fresh milk, they are the major products of fermentation by lactic acid bacteria.

Lactic acid added to fresh milk decreased pH and increased electrical conductivity of milk. We compared the conductivity curves for addition of lactic acid to raw milk and to deionized water. Figure 1 shows that when the same quantity of lactic acid is added to milk and water, the curve for electrical conductivity increase is parallel to that of water, but with lower absolute values (Figure 2). Acidification of milk caused changes in salt equilibrium. The lower incrementally increase in conductivity is due to the uptake of protons by the buffers present in milk.

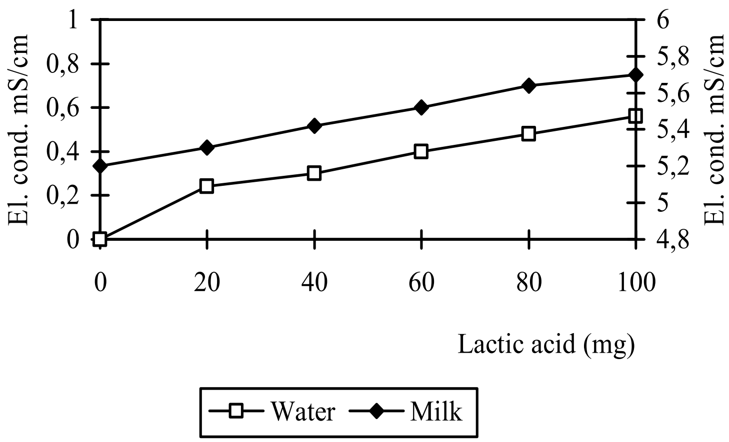

Figure 1. Variation of electric conductivity with lactic acid concentration in water and milk

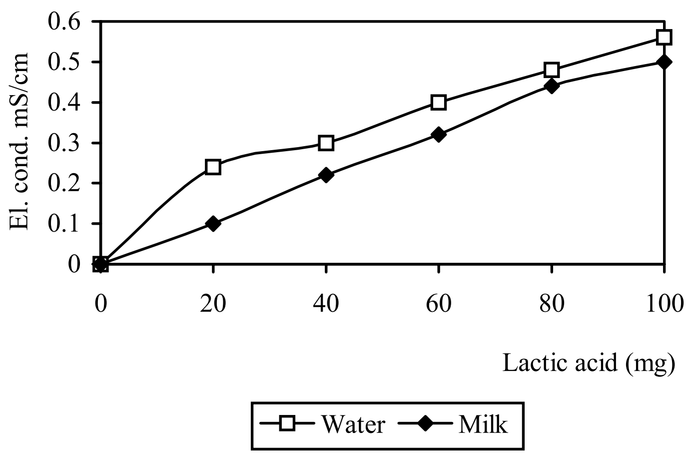

Figure 2. The incrementally increase of electric conductivity as a function of progressive addition of lactic acid

The monophophate ion (HPO_4^{2-}) changes into diphophate ion ($H_2PO_4^-$) as pH decreases. $H_2PO_4^-$ has a lower molar conductivity (36 S cm^2/mol) than HPO_4^{2-} (114 S cm^2/mol) [5], and the addition of lactate only partially compensates for the decrease in conductivity.

$$HPO_4^{2-}{}_{(aq)} + H^+{}_{(aq)} \leftrightarrow H_2PO_4^-{}_{(aq)}$$

Water electrical conductivity increased with 0.5 mS/cm which is similar to the conductivity during fermentation.

CONCLUSIONS

Milk has conductive properties because it is rich in charged compounds, especially mineral salts.

Milk acidification and the decrease of pH are due to the lactose fermentation when lactic acid is formed.

The variation of the electrical conductivity incrementally with variation of lactic acid concentration makes possible the use of this biophysical parameter for monitoring milk acidification.

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