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STABILITY OF MILK CONCENTRATES IN HOT COFFEE

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The aim of the present study was to determine the effects of temperature, the strength of coffee infusions and the addition of saccharose and $CaSO_4$ on the degree of reconstitution of selected milk concentrates. The following coffee additives were used: dried milk concentrates (instant whole milk powder, skim agglomerated milk powder and coffee whitener "Cremilka"), evaporated UHT milk, 12% UHT coffee cream and 1.5% UHT milk.

It was found that the stability and degree of reconstitution of milk concentrates were related primarily to temperature and the strength of coffee infusions (the lower the temperature and the strength of coffee infusions, the higher the degree of reconstitution), followed by water hardness (the addition of 0.001 mol/L $CaSO_4$ caused an increase in the amount of residues) and the addition of saccharose.

INTRODUCTION

Natural coffee additives are gaining wide popularity nowadays. They enrich both the flavor and appearance of coffee, and raise pH levels. Their important health-related advantages include chyme alkalisation, reduced hydrochloric acid secretion and inhibition of the development of chronic gastric and duodenal ulcer diseases [Kolanowski, 1998; Kłobukowski, 1999]. Popular coffee additives are dried milk concentrates, evaporated milk, coffee cream, liquid milk and coffee whiteners. Such products should be characterised by good reconstitution in hot water and resistance to the low pH of coffee. The suitability of milk concentrates as coffee and tea additives is estimated using specially designed tests, such as low shear solubility test, hot water test and coffee test [Baldwin *et al.*, 1982; Teehan *et al.*, 1997].

Milk proteins enter into reactions with tannins, which gives coffee a pleasant, slightly creamy taste. The tart taste of coffee, which results from the presence of tannins, is considered undesirable and unpleasant by some consumers [Kelly *et al.*, 1999].

The aim of the present study was to determine the effects of temperature, the strength of coffee infusions (coffee test) and the addition of saccharose and $CaSO_4$ on the degree of reconstitution of selected milk concentrates.

MATERIALS AND METHODS

The following products obtained under industrial conditions according to the relevant standards were used in the study: instant whole milk powder, skim agglomerated milk powder, instant coffee whitener "Cremilka", evaporated UHT milk, 12% UHT coffee cream, and 1.5% UHT milk.

The above products were reconstituted in instant coffee Jakobs Crönung. The infusions were made by pouring 200 mL of hot water over 1.6 g, 3.0 g and 5.0 g of coffee. According to the experimental design, 12 g of saccharose or 0.001 mol/L $CaSO_4$ were added to some coffee infusions. The temperature of infusions prior to milk concentrate addition was 70°C, 80°C and 90°C.

The following determinations were made on the samples, using universally accepted methods: wettability [Sørensen *et al.*, 1978], dispersibility [Sørensen *et al.*, 1978], and solubility [Sørensen *et al.*, 1978]. The coffee test was also performed [Teehan *et al.*, 1997].

In the coffee test 4.0 g of instant whole milk powder was added to 200 mL of coffee infusion (the other products were converted to dry matter). The solution was stirred for 6 s (6 times in a clockwise direction and 6 times in an anticlockwise direction) and set aside for 10 min. The mixture was poured into 50 mL calibrated centrifuge tubes (ADMI) and set aside for another 5 min. Then the tubes were placed in a K70 D Janetzki centrifuge and centrifuged for 5 min at a centrifugal force of 164 *g*, and the amount of residues (mL) was read off from the scale.

RESULTS AND DISCUSSION

It was found that skim agglomerated milk powder was characterised by the best wettability time (19 s) at 20°C (Table 1). At the same temperature the wettability time of instant whole milk powder, instant coffee whitener "Cremilka" and coffee was 45 s, 47 s and 17 s, respectively.

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TABLE 1. Wettability time, dispersibility and index of solubility of milk concentrates.

Product	Wettability time (s)	Dispersibility (%)	Index of solubility (mL)
Instant whole milk powder	45	92.5	<0.05
Skim agglomerated milk powder	19	94.5	<0.05
Instant coffee whitener "Cremilka"	47	95.5	<0.05
Evaporated UHT milk	-	-	<0.05
12% UHT coffee cream	-	-	<0.05
1.5% UHT milk	-	-	<0.05
Jakobs Crönung coffee	17	-	<0.05

The reason for a slightly longer wettability time recorded in milk powder is most often the presence of the so-called free fat on the surface of particles. Due to that, the boundary values for this form of fat should not exceed 0.03–0.05%. Lecithin placed on the surface of milk powder particles during the instantisation process decreases the level of free fat, thus improving its wettability. Oldfield *et al.* [2000] reported that the addition of lecithin improves the stability of milk powder in hot coffee, but the mechanism preventing its precipitation has not been fully investigated yet. This phenomenon may be a consequence of interactions between lecithin and fat globule membranes, leading to an increase in the charge, which according to Mc Crae & Muir [1992, 1993], has a positive effect on the stability of the whole emulsion system in acid coffee infusions.

The pattern of dispersibility changes was slightly different. The highest degree of dispersibility was recorded in instant coffee whitener "Cremilka" – 95.6% and skim agglomerated milk powder – 94.5%, followed by instant whole milk powder – 92.3%. Żbikowska & Żbikowski [2000] demonstrated that reduced dispersability of milk powder is usually caused by low bulk density, high air content, small size of particles and low wettability. According to these authors, good quality agglomerated or instant milk powder should have wettability time <30 s and dispersibility >90%.

The index of solubility was below 0.05 mL in all samples, which means that it satisfied the requirements of relevant standards [ADMI, Bull. 916; Polish Standard, PN-92/A-86024].

Coffee test

The results of the present study show that 1.5% UHT milk and 12% UHT coffee cream were characterised by the highest reconstitution in hot coffee (<0.05–0.08 mL of

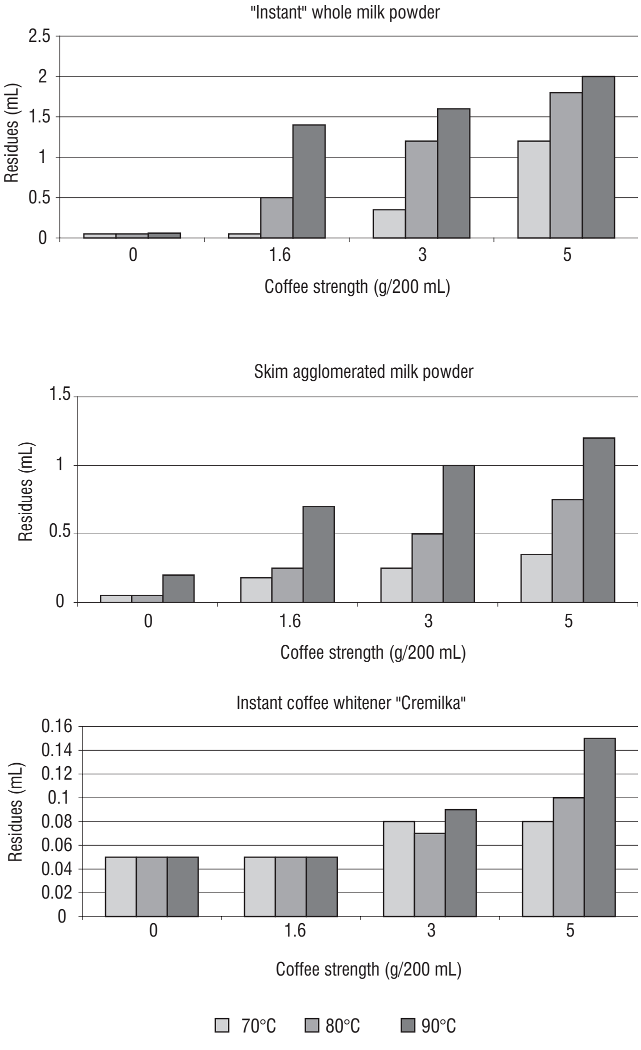


FIGURE 1. Effects of temperature and coffee strength on the amount of residues in the coffee test.

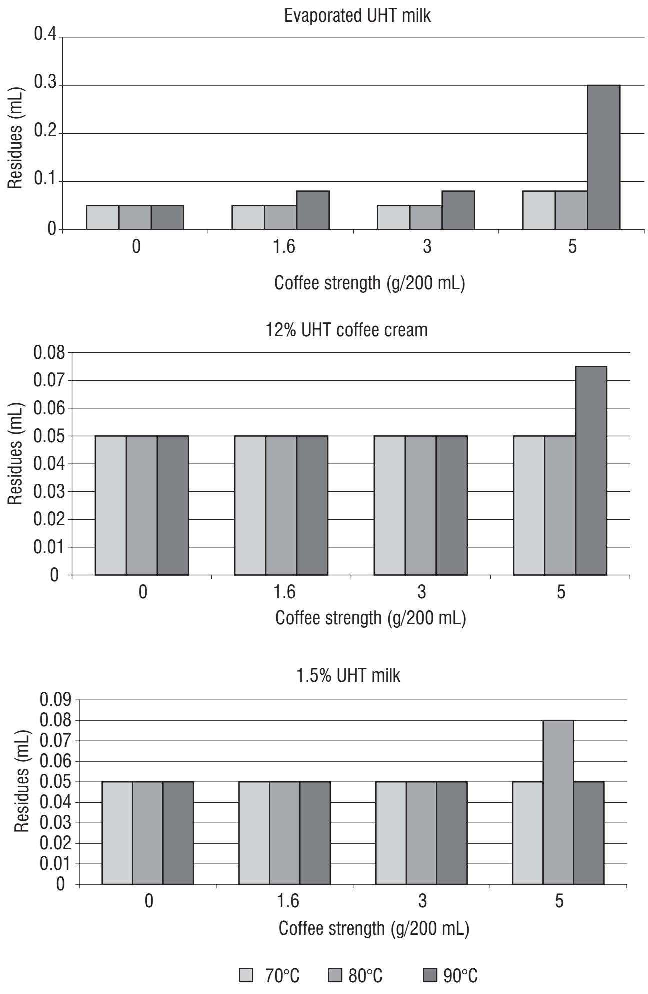


FIGURE 2. Effects of temperature and coffee strength on the amount of residues in the coffee test.

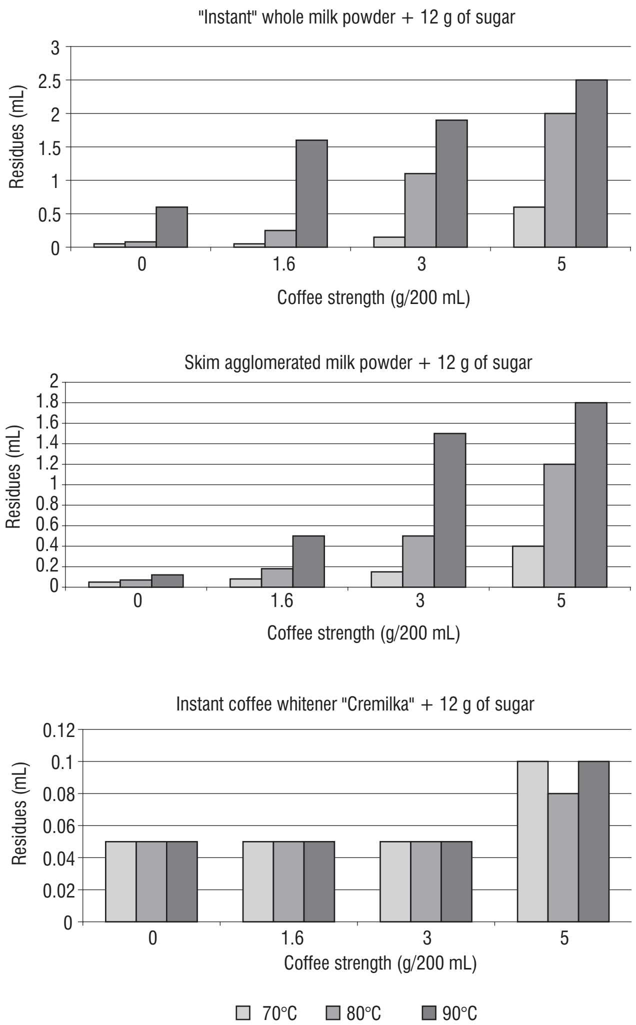
residues and <0.05–0.075 mL of residues, respectively), and instant whole milk powder – by the lowest (0.05–2.0 mL of residues) (Figures 1 and 2). In all samples the amount of residues depended on the increase in temperature and strength of coffee infusion. An increase in the amount of residues was observed in the case of combined effects of temperature and strength of coffee infusion. Instant coffee whitener "Cremilka" and evaporated UHT milk showed satisfactory stability. In these products only extreme conditions (regarding both temperature and coffee infusion strength) resulted in a considerable increase in the amount of residues (0.15–0.40 mL of residues).

Oldfield *et al.* [2000] reported that the stability of milk powder is related to the intensity of milk heat treatment. The amount of residues in the coffee test with milk processed at 75°C/30 s and at 97.5°C/2 min was 0.33 mL and 1.15 mL, respectively. Teehan *et al.* [1997] demonstrated that an increase in temperature from 20°C to 90°C in the coffee test was followed by a decrease in the protein content of residues, from 0.49% to 0.33%, and an increase in the amount of residues to 3 mL. Oldfield *et al.* [2000], who subjected milk to heat treatment to reach a temperature of 75°C and 120°C, observed an increase in the residues of β-casein, β-lactoglobulin and α-lactalbumin by 3.4%, 5.4% and 0.5% respectively, accompanied by a decrease in the levels of α_s-casein and κ-casein by 7.7% and 1.5%, respectively. These authors also found that other key factors deteriorating milk powder stability in the coffee test are high temperature and evaporation time. According to Teehan *et al.* [1997], the amount of residues in the test coffee for stable and unstable milk powder should be <0.05 mL and >1.0 mL, respectively.

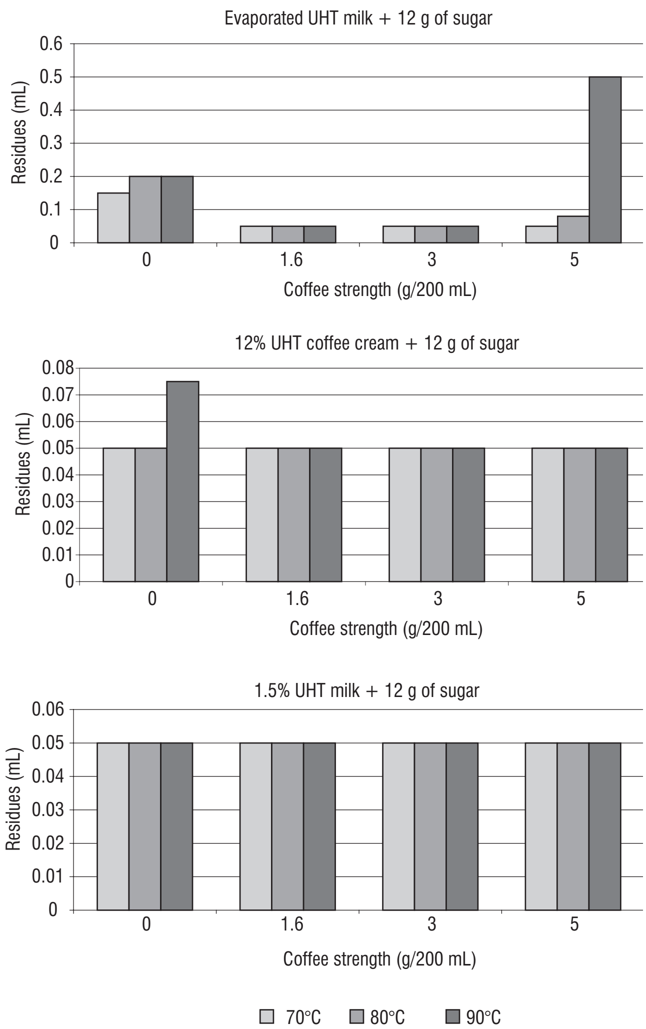
The results of this experiment indicate that the amount of residues may also be affected by the pH of coffee infusions. For instance, in the control sample (without coffee) with instant whole milk powder the amount of residues was 0.60 mL at 90°C, and in the sample with coffee, at a lower pH (5.41) – 2.00 mL (Figure 1). These results are consistent with those obtained by Teehan *et al.* [1997] who found that pH reduction from 6.5 to 6.2 caused an increase in the amount of residues, from <1.0 mL to 4.0 mL. According to these authors, such a significant increase in the amount of residues may be caused by the so-called acid shock, resulting from a too low pH of coffee infusions.

Literature data show that an increase in water temperature causes a decrease in water pH. At 20°C the pH of water is 7.00, whereas at 70°C, 80°C and 90°C – 6.407, 6.306 and 6.210, respectively [Mizerski, 1993].

The addition of saccharose, in the amount of 12 g/200 mL, to coffee infusion had an ambiguous effect on the amount



FIURE 3. Effects of temperature, coffee strength and saccharose on the amount of residues in the coffee test.



4. Effects of temperature, coffee strength and saccharose on the amount of residues in the coffee test.

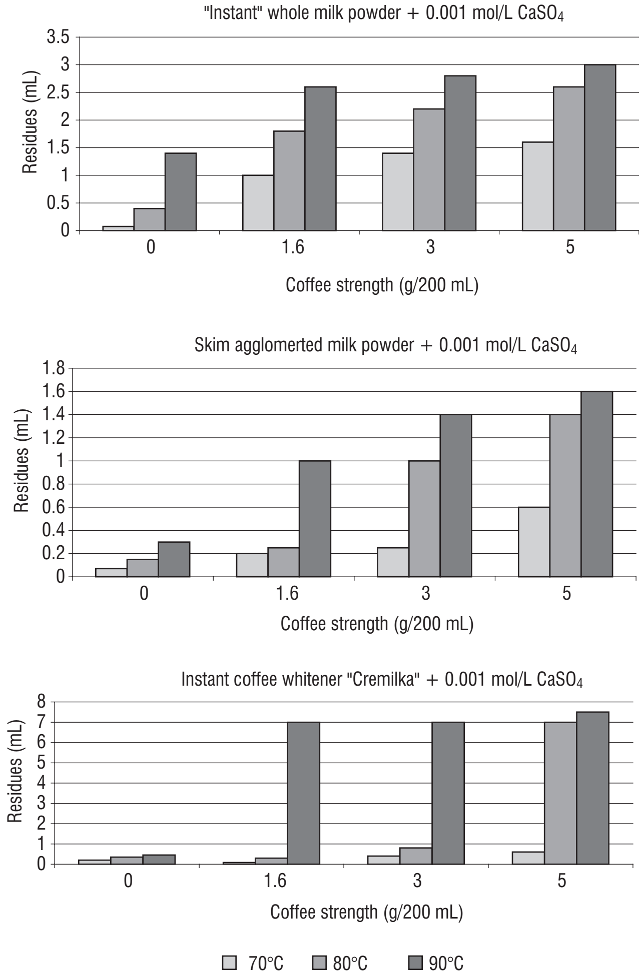


FIGURE 5. Effects of temperature, coffee strength and calcium sulfate on the amount of residues in the coffee test.

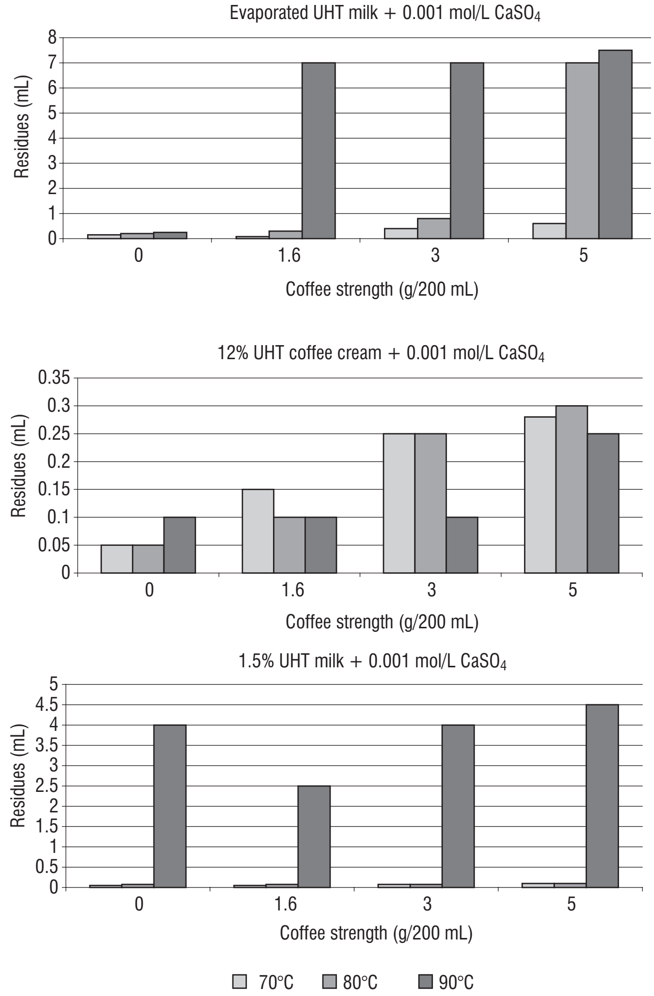


FIGURE 6. Effects of temperature, coffee strength and calcium sulfate on the amount of residues in the coffee test.

of residues in the coffee test (Figures 3 and 4). A more significant effect of the addition of this sugar was observed in instant whole milk powder (0.05–2.50 mL) and skim agglomerated milk powder (0.08–1.80 mL), and a less significant – in evaporated UHT milk (<0.05–0.50 mL), instant coffee whitener "Cremilka", 12% UHT coffee cream and 1.5% UHT milk (<0.05–0.07 mL). Available literature provides no information on the effects of the addition of sacchrarose on the stability of milk concentrates in hot coffee.

The addition of 0.001 mol/L of calcium sulfate to coffee infusion considerably affected the amount of residues in the coffee test (Figures 5 and 6). In this experimental design the lowest stability, especially at 90°C, was recorded in evaporated UHT milk (0.08–7.50 mL), followed by 1.5% UHT milk (0.05–4.50 mL), instant whole milk powder (1.00–3.00 mL), skim agglomerated milk powder (0.20–1.60 mL), instant coffee whitener "Cremilka" (0.07–0.20 mL) and 12% UHT coffee cream (0.15–0.30 mL). The distinctly lower stability of evaporated UHT milk in coffee infusion, and lower stability of milk powder, could be caused by quite restrictive production parameters. In addition, an increase in the concentration of Ca^{++} in coffee infusion contributes to protein denaturation and aggregation.

Teehan *et al.* [1997] proved that water hardness also affects the amount of residues in the coffee test. The addition of 260 mg/L $CaCO_3$ to coffee infusion caused an increase in the amount of residues, to 3.0 mL for stable milk powder and to 4.0 mL for unstable milk powder. Oldfield *et al.* [2000] also confirmed the effect of water hardness (resulting primarily from the concentration of Ca^{++}) on the amount of residues in the coffee test. When hard water and milk heated at 75°C, 94°C and 120°C were used, the amount of residues increased from 0.1 mL (in the control sample with deionised water) to respectively 2.0 mL, 4.0 mL and 4.6 mL. These results are consistent with the findings of Baldwin *et al.* [1982], who observed significant differences in the amount of residues in the coffee test resulting from a simultaneous increase in water temperature and hardness (from 3.37 mL and 8.61 mL at 80°C and 90°C without $CaSO_4$, to 5.60 mL and 10.27 mL at 80°C and 90°C with 0.001 mol/L $CaSO_4$). Oldfield *et al.* [2000] suggested that the amount of residues in the coffee test depends also on the level of undenaturated whey proteins in instant milk powder, which is consistent with previous studies conducted by Sweetsur [1976]. This author found a positive correlation (r=+0.86) between the amount of residues in the coffee test and the casein number, wettability time (r=+0.75) and the index of solubility (r=+0.72), and a negative correlation between coagulation time (r=-0.69) and dispersibility (r=-0.88). Mc Kinnon *et al.* [2000] reported that coffee and tea are not conducive to reconstitution of milk concentrates. This results, among others, from high concentrations of proteins and mineral salts on the concentrate/coffee interface, promoting protein aggregation and precipitation at reduced pH.

CONCLUSIONS

1. 1.5% UHT milk and coffee cream showed the best stability in coffee infusions (<0.05–0.08 mL and <0.05–0.75 mL, respectively), followed by instant whole milk powder (0.05–2.0 mL).

2. The amount of residues in the samples was related primarily to temperature and the strength of coffee infusions. The stability of milk concentrates improved greatly at lower parameters of reconstitution.

3. The addition of $CaSO_4$ to coffee infusions reduced the stability of milk concentrates to a higher degree than the addition of saccharose.

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STABILNOŚĆ KONCENTRATÓW MLECZNYCH W GORĄCEJ KAWIE

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Niniejsze badania dotyczyły określenia wpływu temperatury i mocy naparów kawowych oraz dodatku sacharozy i $CaSO_4$ na stopień rekonstytucji wybranych koncentratów mlecznych. Jako dodatki do kawy stosowano suszone koncentraty mleczne (proszek mleczny pełny "instant", odtłuszczony "granulowany", zabielacz "cremilka"), mleko zagęszczone niesłodzone UHT, śmietankę 12% UHT i mleko 1,5% UHT.

Stwierdzono, że stabilność i rekonstytucja koncentratów mlecznych zależała w największym stopniu od temperatury i mocy naparów kawowych (im niższa temperatura i moc naparów, tym lepszy stopień odtworzenia). Najlepszą stabilnością w naparach kawowych charakteryzowało się mleko 1,5% UHT (<0,05–0,08 mL) i śmietanka (<0,05–0,075 mL), a niższą proszek mleczny pełny "instant" (0,05–2,0 mL). Również dodatek 0,001 mol/L $CaSO_4$ do naparów kawowych w bardziej znaczącym stopniu wpłynął na wzrost ilości osadu w rekonstytuowanych koncentratach, niż dodatek sacharozy.