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Development of Dairy-Based Spread Selection of Levels of Ultrasonication Parameters

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ABSTRACT

A study was conducted to determine the effect of ultrasonication on the sensory and physical properties of dairy-based spread. The fat phase of the spread contains butter and sunflower oil. The aqueous phase consists of butter milk powder, whey protein concentrate and salt. Ultrasonication was performed using a 20 kHz Ultrasonicator (Cole-Parmer, USA) at varying amplitudes (20%, 30%, and 40%) and durations (10, 20, and 30 minutes) at 40°C. It was found that certain combinations of amplitude and duration significantly influenced the quality of the fat spread. Also, emulsion stability and spreadability were assessed for all treatments using modified methodologies for identifying optimal conditions for producing a superior fat spread product.

Keywords: Ultrasonication, Fat spread, Butter milk powder, Whey protein concentrate

INTRODUCTION

Fat spread is a product in the form of a water-in-oil (w/o) emulsion. The fat phase of spread may contain edible oil, fats, emulsifier, and other fat-soluble ingredients, and the aqueous phase may contain salt, stabilizer and other water-soluble ingredients. According to FSSAI (2022), fat spreads must have a fat content not less than 40% and not more than 80% by weight, and a moisture content not less than 16% and not more than 56% by weight.

Ultrasonication is one of the new, fast and emerging technologies in the field of food science and technology. Ultrasound consists of sound waves with frequencies exceeding 20 kHz, beyond the audible range for humans. Ultrasonication is reported as a high-energy emulsification technique that creates emulsions with smaller droplet sizes through the physical effects generated by acoustic cavitation in liquids, including mechanical vibrations, acoustic streaming, acoustic cavitation, microstreaming, shear and turbulence (Li and Fogler, 1978; Ashokkumar *et al.*, 2010; and Abbas *et al.*, 2013). The present study aimed to determine the optimum amplitude and duration of ultrasonication to develop a fat spread with enhanced emulsion stability, spreadability and improved sensory attributes.

MATERIALS AND METHODS

This work was conducted using a 20 kHz Ultrasonicator (Cole-Parmer, USA) installed at the Verghese Kurien Institute of Dairy and Food Technology in Mannuthy, Thrissur, Kerala. For the preparation of the fat spread, a mixture of sunflower oil and butter was used as the fat phase. Buttermilk powder (BMP), whey protein concentrate (WPC) and water were used as the aqueous phase. The fat content of the fat spread was standardized to 40%. The mixture of the fat phase and aqueous phase was ultrasonicated at different amplitudes (20%, 30% and 40%) and durations (10, 20 and 30 minutes). The temperature of the process was maintained at 40°C using a water bath.

In the first phase of the experiment, spread samples were ultrasonicated for 30 minutes at amplitudes of 20% (A1), 30% (A2) and 40% (A3), respectively. In the second phase, the spreads were prepared by varying the duration of ultrasonication, viz., 10 (T1), 20 (T2) and 30 (T3) minutes at 30% amplitude. Emulsion stability was determined using the methodology outlined by Szymanska *et al.* (2021), with some modifications in the weight of the sample taken (5g). Spreadability analysis was conducted as per Rege *et al.* (2013) with some modifications. A glass plate weighing 258g was used in place of the 244.26g glass plate.

Statistical analysis

Results obtained were statistically analysed using ANOVA and the Kruskal-Wallis test using the statistical software IBM SPSS Version 22.0.

RESULT AND DISCUSSION

The spreadability, emulsion stability and sensory scores of fat spread treated at different amplitudes (20, 30 and 40%) are given in Figure 1 and Table I. There was no significant difference between the spreadability of samples treated at different amplitudes and the control. However, the emulsion stability of the samples treated at 30% and 40% amplitudes was significantly higher compared to the control ($p \leq 0.05$). The emulsion stability of the sample treated at 20% amplitude was the lowest and was similar to that of the control.

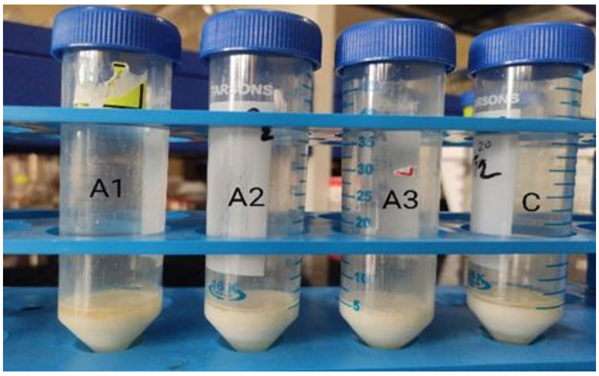

Figure 1: Ultrasonication at different amplitudes - Image showing emulsion stability of spread at different amplitudes (A_1- 20% amplitude, A_2- 30% amplitude, A_3- 40% amplitude for 30 min., C-Without ultrasonication)

Table 1: Effect of amplitude of ultrasonication on the sensory and physical properties of low-fat spread

Samples	Emulsion stability (%)	Spreadability (mm^2)	Sensory evaluation scores				
			Colour and appearance	Body and texture	Flavour	Spreadability	Overall spreadability
A1	94.26±0.40^{a}	9.52±3.50^{a}	7.50±0.24^{a}	6.93±0.28^{a}	6.14±0.46^{a}	7.43±0.30^{a}	6.36±0.36^{a}
A2	96.43±0.31^{b}	7.17±1.18^{a}	7.50±0.19^{a}	6.93±0.17^{a}	7.36±0.24^{b}	7.36±0.18^{a}	7.00±0.11^{a}
A3	99.34±0.17^{c}	6.83±1.94^{a}	7.57±0.20^{a}	6.79±0.21^{a}	6.64±0.32^{ab}	7.29±0.29^{a}	6.71±0.29^{a}
C	93.84±0.58^{a}	8.90±1.59^{a}	7.86±0.14^{a}	7.43±0.20^{a}	7.57±0.3^{b}	7.71±0.18^{a}	7.93±0.17^{b}

n=3, Values are mean ± Standard Error, means superscripted with different lower-case letters (a-c) in the same column differ significantly ($P \leq 0.05$)

No significant difference was observed in the colour and appearance, body and texture and spreadability scores of low-fat dairy spread prepared using ultrasonication at different amplitudes. However, the flavor scores of fat spread decreased significantly with ultrasonication. Similar observations were reported by Kenari and Razavi (2021). They observed decreased flavour scores in yoghurt with increasing amplitude and duration of ultrasonication. The treatment A3 showed maximum emulsion stability. However, an unnatural flavor was observed in the sample treated at 40% amplitude. A similar flavor issue was also observed in A1. The overall acceptability of control was significantly high compared to the samples prepared using ultrasonication at different amplitudes. The development of off-flavour in ultrasonicated fat spread may be due to the formation of volatiles during ultrasonication of milk fat (Chouliara, 2010 and Paniwnyk, 2017). The ultrasound has proven to be efficient for producing stable emulsions. However, the temperatures and shear conditions present can result in the generation of hydroxyl and hydrogen radicals, leading to lipid oxidation and deterioration of the milk product containing fat. Milk stability and lipid oxidation during storage, examined after ultrasonic treatment at various frequencies and specific energies, showed that lipid oxidation in milk can be controlled by reducing sonication time and temperature, and that it is dependent upon the fat content of the treated milk (Juliano *et al.*, 2014).

The sensory evaluation results showed that low-fat spread prepared using ultrasonication at 30% amplitude (A2) had a higher overall acceptability score compared to that of samples A1 and A3. Although the sample A2 scored higher overall acceptability, the differences between A2 and the other samples were not statistically significant. However, the flavour score of A2 was significantly higher than that of A1 and A3, showing a notable improvement in flavor. This difference was statistically significant. Further, flavor score of A2 was statistically similar to that of the control. Therefore, the treatment A2 was selected as the most appropriate amplitude based on its emulsion stability, spreadability and sensory score.

From the Figure 2 and the data given in Table II, it is clear that, with an increase in duration of ultrasonication, there is no change in the sensory attributes of samples T1 and T2. Therefore, the sample treated at 30% amplitude for 10 minutes (T1) was selected as the best. Ultrasonication directly affects the emulsion stability and flavour of the product. Increasing the duration and amplitude of ultrasonication significantly reduces the rich flavor of the spread. The sample treated with 30% ultrasonication for 10 minutes achieved desirable emulsion stability, spreadability and overall acceptability.

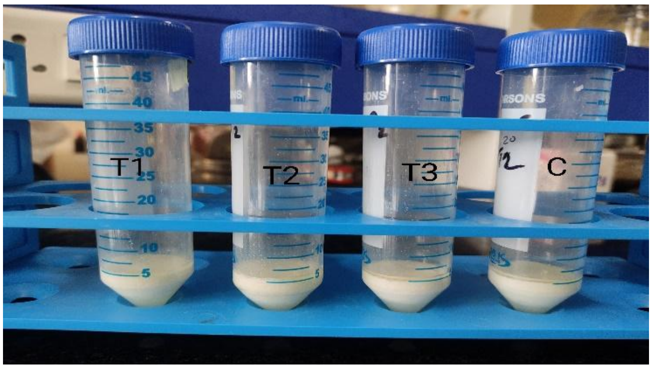

Figure 2: Ultrasonication at different durations - Image showing emulsion stability of spread at different durations (T_1- 10 minutes, T_2- 20 minutes, T_3- 30 minutes for 30% amplitude, C- Without ultrasonication)

Table 2: Effect of duration of ultrasonication on the sensory and physical properties of low-fat spread

Samples	Emulsion stability (%)	Spreadability (mm^2)	Sensory evaluation scores				
			Colour and appearance	Body and texture	Flavour	Spreadability	Overall acceptability
A1	96.94±.29^{bc}	8.22±1.93^{a}	7.89±0.11^{a}	7.78±0.14^{a}	7.06±0.21^{b}	7.56±0.18^{a}	7.17±0.17^{b}
A2	97.81±.47^{c}	7.97±2.04^{a}	7.89±0.11^{a}	7.78±0.14^{a}	6.69±0.20^{b}	7.67±0.17^{a}	7.03±0.33^{b}
A3	96.12±.03^{b}	7.81±1.81^{a}	7.77±0.15^{a}	7.44±0.24^{a}	5.83±0.35^{a}	7.67±0.17^{a}	6.06±0.39^{a}
C	94.23±.42^{a}	8.89±1.58^{a}	8.11±0.1^{a}	8.00±0.16^{a}	7.92±0.08^{c}	8.00±0.17^{a}	8.06±0.13^{c}

n=3, Values are mean ± Standard Error, means superscripted with different lower-case letters (a-c) in the same column differ significantly ($P \leq 0.05$)

Chouliara *et al*. (2010) observed that the concentrations of volatile compounds such as pentanal, hexanal, heptanal, and octanal increased with longer sonication treatments. Pentanal, hexanal, heptanal, and octanal are well-known secondary oxidation products of unsaturated fatty acids, formed through a free radical mechanism. This increase is attributed to the pyrolysis of compounds during sonication, leading to enhanced lipid oxidation. The formation of these aldehydes, known secondary oxidation products, supports the hypothesis that ultrasonication promotes lipid oxidation.

CONCLUSION

This study aimed to optimize the combination of ultrasonication amplitude and duration to achieve a product with excellent sensory quality. Ultrasonication was utilized for encapsulating various functional ingredients and enhancing emulsification properties. It was found that certain combinations of amplitude and time led to the development of an unpleasant flavor, specifically at A1 and A3. The unnatural flavor development may be due to the production of other fat-hydrolysed products. Future studies are advocated for characterizing the flavor compounds responsible for off-flavour in fat-rich dairy products during ultrasonication.

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