ANALYSIS OF PHYSICOCHEMICAL PROPERTIES AND FUNCTIONAL QUALITY ATTRIBUTES OF SHELF AVAILABLE MILK POWDERS IN SRI LANKA USING FOURIER TRANSFORM INFRA-RED TECHNOLOGY AND SCANNING ELECTRON MICROSCOPY

W. V. V. R. Weerasingha[1], M. Gunawardena[2], S. V. R. Weerasooriya[2] and J. K. Vidanarachchi*[1]

[1]Department of Animal Science, Faculty of Agriculture, University of Peradeniya

[2] Sri Lanka Institute of Nanotechnology, Homagama

**Corresponding author (email: janakvid@pdn.ac.lk)*

Introduction

Milk is one of the most common and nutritious food sources of human diet which is highly susceptible to spoilage due to the action of spoilage bacteria and naturally occurring enzymes. Milk powder production is the most common processing method used in the dairy industry for preservation of milk. Milk powder is produced by partial removal of water from liquid milk to dryness. Major purposes of milk powder production are preservation of liquid milk and obtain a prolonged shelf life with little or no detrimental changes compared to original liquid milk. It has become increasingly important product with wide range of end use applications where it requires compositional consistency, desirable physical attributes and functional properties.

Since milk powder solubility is considered as one of the major functional properties, poor reconstitution of milk powders acts as a limiting factor in different food applications [1]. Insolubility may affect processing difficulties and economic losses as well as negatively affect other functional properties of milk powders such as emulsification, gelation, foaming and whipping properties.

The objective of this study was to investigate the physicochemical properties of shelf available milk powders that are commonly available in Sri Lankan market and compare them with the international quality standards. Solubility was measured as one of the major functional properties of the milk powders. Microstructure of the milk powder samples were obtained using Scanning Electron Microscopic images and compositional differences were evaluated using Fourier Transform Infra-Red (FTIR) spectroscopy which is one of the fastest and direct methods that can be used to evaluate the compositional changes of powdered milk.

Materials and Methods

Experiment was performed using most commonly available four imported milk powder brands (Brand A, B, C, D) and two locally produced milk powder brands (Brand E, F) available in Sri Lankan market.

Solubility Determination and Chemical Property Analyses

Solubility was measured by insolubility index method [2]. Powder samples were analyzed for proximate composition [3]. Total protein was determined by Kjeldahl method. Ash content was gauged by ignition at 550°C in an electric muffle furnace. Fat content was determined by Soxhlet method with the modification of extended time of 10 hours and free moisture content by oven-drying method. Free fatty acid content of milk powder samples was determined using extraction titration method. Total *Ca* content of the powders was analyzed using atomic absorption spectrophotometer (AA-6200, Shimadzu, Japan). Water activity of powder samples were determined using water activity meter (Hygrolab 3, Rotonic Instruments, Japan) and pH determination was carried out using a pH meter (Model: 775249 Eutech, Singapore).

Physical Property Analyses

Untapped bulk density and tapped bulk density of milk powder was determined as described by Suleiman et al (2014) [4].

Microstructural analyses

Scanning Electron Microscopy (SEM) was used to evaluate the microstructure of the powder particles. The samples were gold coated by sputtering and analyzed using SEM instrument (EVO 15, Zeiss, German) operating at 10 kV under the magnification levels of 250×, 500×, 1000×.

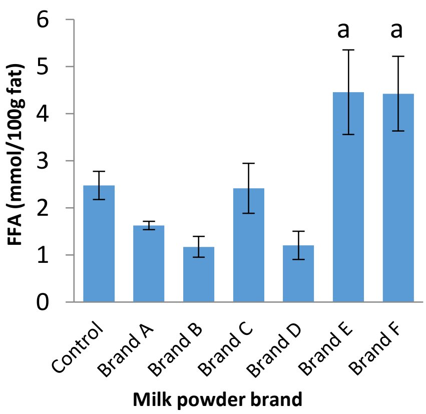
FTIR spectrum analyses

Milk powder compositional changes were analyzed using an Attenuated Total Reflection Fourier Transform Infra-Red (ATR- FTIR) spectrometer (Nicolet IS 50, Thermo Scientific) with an Attenuated Total Reflection cell (Universal ATR).

Statistical analyses

Significance of each physical and chemical property among milk powder brands were analyzed using Complete Randomized Design (CRD). Mean separation was done by Duncan's Multiple Range Test and relationship between each physicochemical property with solubility was analyzed using regression and correlation. Data analysis was done by SAS (9.2 version) software.

Results and Discussion



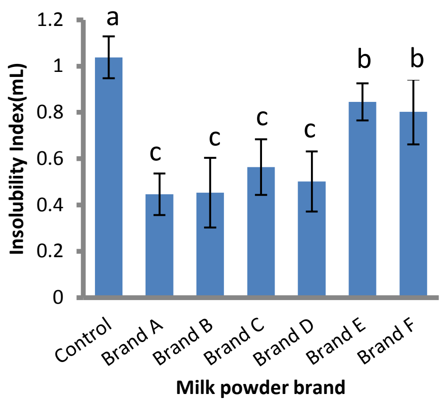


Figure 1. Variation of insolubility index of commercially available milk powders in Sri Lanka

b
b
bc
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c

Figure 2. Variation of free fatty acids levels in commercially available milk powders in Sri Lanka

Table avail

Milk powder brand	Protein content (%)	Fat content (%)	Moisture content (%)	Water activity	Ca content (mg/Kg)	Ash content (%)	pH
Accepted level	24.5-27	26 - 42	<5	0.2-0.6	<10000	5.5-6.5	6.5-6.7
Control	29.4±2.5^{a}	17.1±0.4^{d}	1.0±0.2^{c}	0.30±0.01^{d}	7363±135^{a}	6.70±0.4^{a}	7.06±0.13^{a}
Brand A	23.6±0.4^{d}	29.3±1.9^{a}	2.5±0.6^{ab}	0.38±0.02^{a}	4246±470^{c}	5.60±0.6^{c}	6.88±0.09^{ab}
Brand B	23.7±0.5^{d}	26.6±1.0^{ab}	3.1±1.0^{a}	0.39±0.00^{a}	4713±310^{bc}	5.25±0.2^{c}	6.74±0.27^{bc}
Brand C	20.3±0.9^{e}	23.3±1.3^{c}	2.0±1.1^{abc}	0.39±0.02^{a}	4457±622^{bc}	4.05±0.3^{d}	6.74±0.28^{bc}
Brand D	24.3±0.3^{cd}	26.6±1.8^{b}	2.7±1.0^{ab}	0.38±0.02^{ab}	4771±403^{bc}	5.55±0.3^{c}	6.56±0.24^{c}
Brand E	26.4±1.6^{b}	26.3±1.6^{b}	1.7±0.9^{bc}	0.33±0.01^{c}	5678±957^{b}	6.28±0.5^{b}	6.91±0.18^{ab}
Brand F	25.6±1.0^{bc}	23.6±1.2^{c}	2.5±0.8^{ab}	0.36±0.01^{bc}	4973±901^{bc}	5.64±0.2^{c}	7.04±0.17^{a}

All values are presented as the means ± SD for five replicates.
Column mean value with different superscript letters are significantly different at (p<0.05)

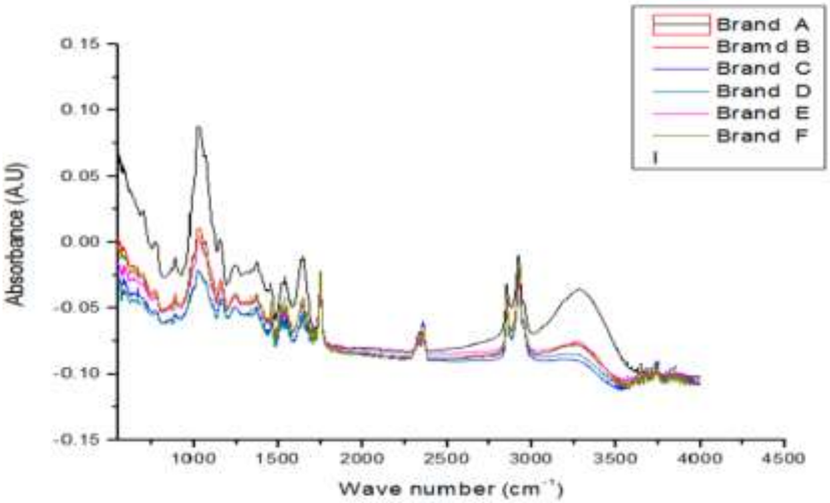
Table 2. Mean bulk density, and particle density of commonly available milk powder brands in Sri Lanka

Powder Brand	Untapped bulk density	Tapped bulk density	Particle density
Control	0.32±0.01^{e}	0.36±0.01^{d}	0.91±0.02^{b}
Brand A	0.43±0.00^{c}	0.55±0.01^{c}	1.15±0.01^{a}
Brand B	0.50±0.02^{ab}	0.61±0.02^{a}	1.14±0.07^{a}
Brand C	0.55±0.06^{a}	0.59±0.01^{ab}	1.15±0.05^{a}

Brand D	0.50± 0.02^{ab}	0.60±0.02^{ab}	1.20±0.07^{a}
Brand E	0.44±0.00^{cd}	0.58±0.01^{b}	0.99±0.04^{b}
Brand F	0.48±0.01^{cd}	0.60±0.01^{ab}	1.11±0.03^{a}

Means with different superscript letters within columns are significantly different (p<0.05)

Chemical property analysis revealed that FFA levels in imported milk powders exist within the acceptable range while it is nearly three times higher than acceptable limits in locally produced milk powders. Milk powder brand C and F contain lower fat contents than standard level. All the other chemical properties including fat, protein, ash, Ca, moisture and water activity were within the acceptable standard levels in both local and imported milk powders. Imported milk powder brands had higher bulk density and particle density than local brands except the imported milk powder brand 'A' which showed the lowest bulk density and particle density values



in physical property analysis.

Figure 3. Comparison of absorption spectrum, in wavenumber 400-4000cm^{-1} of shelf available milk powder brands

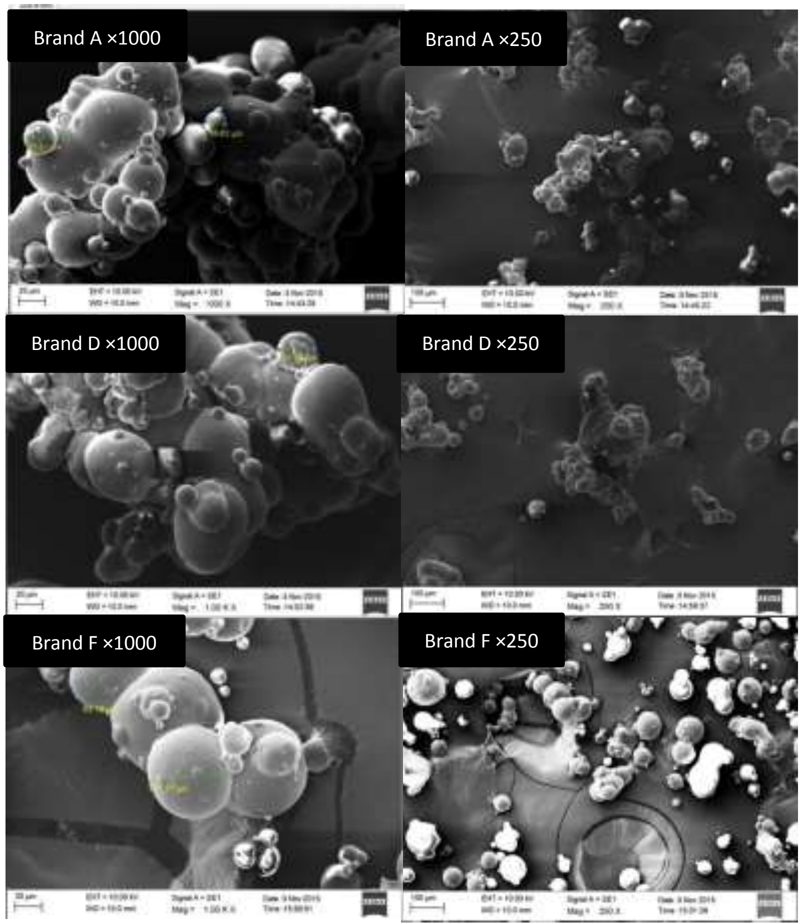


Figure 4: Scanning Electron Microscopic images of milk powder under x1000, x250 magnification

According to the FTIR spectra (Figure 3), all milk powder samples had distinct fingerprint characteristics with regard to main nutrients including lipid, protein and carbohydrates. Brand A had very clear high absorption intensities at wavenumbers 1000 cm^{-1} and 3200 cm^{-1} indicating the difference of aliphatic amines for C-N stretch bond and primary or secondary amides or amines for N-H stretch bond, respectively.

Solubility is one of the major functional properties of milk powders which mainly depend on the chemical composition and physical state of the milk powders. According to the insolubility index values imported milk powders had higher solubility than the locally produced brands (Figure 1). Scanning Electron Microscopic images confirmed that presence of uniformly agglomerated powder particles in imported milk powder brands while local products appeared with more fine non-agglomerated particles which can be one of the main reasons for inferior solubility of local powders (Figure 4).

Hence, it can be revealed that functionality of milk powders differs significantly due to their compositional and structural changes suggesting differences in processing conditions and quality attributes between locally produced and imported milk powder bands.

Conclusion

Among the physical and chemical properties of imported and locally produced milk powders tested in the current study, free fatty acid content and fat content were not in the international standard levels. According to the FTIR analyses, presence of different functional groups in milk powder brand 'A' could have impact on its higher solubility. Scanning Electron Microscopic images confirmed that presence of uniformly agglomerated powder particles in imported milk powder brands while local products appeared with more fine non-agglomerated particles which can be one of the main reasons for inferior solubility of local powders.

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