PROPERTIES OF MILKS CONCENTRATED BY REVERSE OSMOSIS

A THESIS PRESENTED IN PARTIAL

FULFILMENT OF

THE REQUIREMENTS FOR THE DEGREEE OF

DOCTOR OF PHILOSOPHY IN FOOD TECHNOLOGY

BY

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1998

TO MY GRANDMOTHER
GUNAWATI

ABSTRACT

Reverse osmosis (RO) is an energy efficient way of concentrating milk that can be operated at ambient temperatures, avoiding the product damage associated with thermal processes, and resulting in concentrates with better functional and nutritional properties. The objectives of this study were to examine in detail the effects of RO concentration on the rheological properties of milks, the states of proteins and fat globules in milk, the stability of RO concentrates towards ultra high temperature (UHT) processing, and changes in the UHT sterilized product during storage.

Whole milk, homogenized milk and skim milk were concentrated to 1.5X, 2.0X, 2.5X and 3.0X by RO, and rheological properties were measured at 5, 15, 25, 40 and 60 °C before and after 48 h storage at 5 °C, using a Bohlin VOR rheometer. The values of k (the consistency index) and n (the flow behaviour index) were obtained by analysis of the flow curves using the power law model. These values indicated that the samples were generally very slightly shear thinning (i.e. pseudoplastic). k increased with decreasing temperature and increasing concentration. A shift factor approach was used to develop a relationship between k, temperature and total solids concentration (as n remained virtually constant). The equation can be used to predict the flow behaviour of RO concentrated milk at various total solids contents and temperatures. The data was also analysed using the Fernandez-Martin approach (1972); this was found to be more successful at modelling the effects of concentration and temperature on k.

The viscosity data was also analysed using a hydrodynamic approach by means of Eilers' equation. A closer relationship was found between experimental values of basic viscosity and those predicted values by Eilers' equation when lactose was included in the equation as a component contributing to the volume fraction of the dispersed phase, rather than as a component contributing to the continuous phase viscosity.

Concentration by RO results in inevitable homogenization of whole milk, by the back pressure device needed to maintain the pressure driving force for concentration in the RO plant. Analysis of RO milks by particle size distribution measurement and electron microscopy revealed that the original fat globules were broken up into new globules in the size range 0.02-0.3 µm; these globules were smaller overall than in milks homogenized with conventional valve homogenizers.

The microstructures of protein membranes around the fat globules in RO concentrated milks were very different from those in milks homogenized conventionally. There were very few intact or semi-intact casein micelles at the surfaces of fat globules or in the serum. There were numbers of small fat globules grouped together, apparently held together by quantities of protein. Some unique particles were observed, which appeared to be similar to casein micelles, but had a number of very small fat globules embedded within their structure.

Particle size measurements and electron micrographs of samples clearly showed that UHT treatment of RO concentrated milks resulted in the formation of large aggregates of intact fat globules. This aggregation was protein-mediated and no evidence of fat globule coalescence was observed. When milks containing native fat globule membrane (non-homogenized reblended concentrated milks) were UHT treated, the large aggregates formed consisted of protein alone with no inclusion of fat globules. In RO concentrated milks, the extent of formation of aggregates, as well the aggregate size, decreased with increase in milk pH from 6.3 to 7.2 or with the addition of disodium phosphate (DSP) prior to UHT treatment.

UHT treated RO concentrated milks were examined for physico-chemical and structural changes during storage at 5, 20 and 37 °C. The effects of various processing variables (forewarming prior to concentration, post-UHT homogenization and the addition of phosphates prior to UHT treatment) on the storage-induced changes were also investigated. The results showed that irrespective of processing treatment, there was a decrease in pH with storage time, the extent of pH decrease being greater at higher storage temperatures. Gel formation, determined by a penetration test, correlated with the particle size distribution determined by light scattering. Samples stored at higher temperature showed greater quantities of large particles and gelled more quickly than those stored at lower temperature. The viscosity (measured at storage temperature) increased with storage time, the greater rate of increase being observed at the lowest storage temperature of 5 °C. The non-protein nitrogen content of all samples increased with storage time (indicating protein breakdown), the greatest rate of increase being observed at the highest storage temperature of 37 °C.

Homogenization of concentrates after UHT treatment had no appreciable effect on gel formation during storage for pasteurized milk concentrates, but it decreased the rate of gel formation for concentrates that had been made from milk forewarmed prior to concentration. While forewarming decreased the rate of gelation for homogenized milks, an opposite trend was observed for concentrates that had not been homogenized.

Results from electrophoresis analysis and electron microscopy showed minimum changes in the samples stored at 5 °C, whereas storage of samples at 37 °C for 25 weeks resulted in an increase in non-disulphide covalent cross links, and increases in fibre-like material and proteinacious particles in the serum.

The addition of sodium hexametaphosphate (SHMP) resulted in the formation of smaller aggregates during storage, whereas the addition of DSP resulted in the formation of larger aggregates, suggesting that SHMP provides some stabilization of the concentrates. Electron microscopy and electrophoresis results did not show any significant differences between the samples with added SHMP or added DSP. Based on these results, a gelation mechanism in RO concentrated milks is proposed.

RO concentrated milks have unique structures; recommendation are made for further work aimed at a better understanding of such milks, and at the development of new or improved dairy products that utilize their unique functional properties.

ACKNOWLEDGEMENTS

I wish to thank my chief supervisor, Professor Harjinder Singh, for his excellent supervision, understanding, warm encouragement throughout my study, help with planning of experimental work, his never ending patience in helpful discussions and his generous help in the preparation of this manuscript.

I am thankful to my second supervisor, Dr. Owen J. McCarthy for his advice, guidance, invaluable suggestions, constructive criticism, and help in data analysis and in the preparation of this thesis.

I wish to thank Mr. A.B. McKenna of the New Zealand Dairy Research Institute (NZDRI) for his help in training me in electron microscopy work.

In addition, I would like to thank Ms. June Latham, Mr. Steve Glasgow, Mr. Alistair Young, Mr. Garry Radford, Mr Byron McKillop, Mr. Mark Dorsey, and Mr. John Dawber for technical assistance during experimental work and the writing of this thesis. The help provided by Mr. Doug Hopcroft and Mr. Raymond Bennet (AgHort Research) for developing electron micrographs, and Mr. Peter Mayhill and Mr. Paul Mason (NZDRI) for analysis of particle size distributions is sincerely acknowledged.

I would like to thank all the staff of the Institute of Food, Nutrition and Human Health, Massey University for providing valuable assistance during the course of this project. In particular, I would like to thank Dr. Mike Taylor, Dr. Oswaldo Campanella, Mr. Rod Bennett, Mrs. Toni Snowball Kui, Ms. Karen Pickering, Ms. Wibha Desai and Mr. Bill King.

I am also grateful to my fellow graduates and researchers Dr. Hong Chen, Dr. David Oldfield, Mr. Tasa Havea, Mr. Dinesh Sofat for their friendship and help. Many thanks to Mr. Alaistar Carr for his generous help from time to time.

Special thanks to Dr. P. K. Samal (NZDRI) for friendship, guidance and encouragement from time to time.

I wish to thank the New Zealand Vice Chancellors' Committee for awarding me a Commonwealth Fellowship.

Finally, I would like to thank my parents and sister in India for their moral support throughout the course of this work. Last, but not least, I am grateful to my wife Renu for her long patience, and my daughters, Anu and Ankita for supporting me during this tenure.

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