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**PROPERTIES OF RECOMBINED MILK PROTEIN
COMPOSITE GELS: EFFECTS OF PROTEIN SOURCE,
PROTEIN CONCENTRATION AND PROCESSING TIME**

**A THESIS PRESENTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF TECHNOLOGY
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ABSTRACT

Increased knowledge of the interactions involved in the manufacture of Milk Protein Composite Gels (MPCGs) is essential for the further development of dairy-based analogue and recombined products and the advancement of novel product development. This study investigated MPCG manufacture using four protein sources (Rennet Casein, skim milk cheese (SMC), milk protein concentrate (MPC 85), calcium-depleted milk protein concentrate (IX MPC 85)), three protein to water (P/W) ratios (0.4, 0.5, 0.6) and four processing times (0, 4, 8, 16 minutes). The properties of the products were investigated using confocal and transmission electron microscopy, as well as rheological and functional tests.

Protein source was found to have the greatest impact on product characteristics, followed by P/W ratio with processing time having little, and often inconsistent, effects. Increased protein concentration resulted in a higher viscosity during manufacture, a decrease in fat droplet size, an increase in gel firmness, and a decrease in meltability. Increased processing time resulted in a decrease in fat droplet size, few significant changes in firmness (both small- and large-strain), and an increase in meltability.

Fracture property analysis showed that SMC produced softer, more elastic gels than Rennet Casein. The whey-containing samples produced softer, more brittle gels with little difference between them. Small-strain analysis showed that all samples were weak gels but the results did not follow the same trend as the fracture properties. The samples increased in firmness in the following order: SMC < Rennet Casein < IX MPC 85 < MPC 85.

Microstructure analysis showed the presence of whey protein aggregates in the MPC 85 and IX MPC 85 samples. These samples also demonstrated aggregation of the lipid droplets, which was attributed to the presence of whey proteins. Reduced levels of calcium resulted in lower levels of emulsification (larger lipid droplets) due to lower in-process viscosities.

Correlations between large- and small-strain testing showed that the correlation coefficient was dependent on the protein source being used and that although the level of correlation was not high, there was a general positive trend. The small-strain and UW Meltmeter tests did not agree on the order of increasing meltability except for the SMC samples, which were significantly more meltable than the other protein sources. The two tests were poorly correlated ($R^2 = 0.446$).

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TABLE OF CONTENTS

| | |
|---|-------------|
| ABSTRACT | I |
| ACKNOWLEDGEMENTS | II |
| TABLE OF CONTENTS | III |
| LIST OF FIGURES | VI |
| LIST OF TABLES | VIII |
| NOMENCLATURE | X |
| ABBREVIATIONS | XII |
| 1.0 INTRODUCTION | 1 |
| 2.0 LITERATURE REVIEW | 2 |
| 2.1 MANUFACTURE OF PROTEIN PRODUCTS | 2 |
| 2.1.1 <i>Casein Manufacture</i> | 2 |
| 2.1.2 <i>Manufacture of Milk Protein Concentrate</i> | 3 |
| 2.2 RHEOLOGICAL TESTING | 5 |
| 2.2.1 <i>Introduction</i> | 5 |
| 2.2.2 <i>Large-Strain Testing (Compression Testing)</i> | 6 |
| 2.2.3 <i>Small-Strain Testing (Oscillatory Testing)</i> | 11 |
| 2.2.4 <i>Melt and Flow Characterisation</i> | 14 |
| 2.2.5 <i>Rheological Correlations</i> | 15 |
| 2.3 MILK PROTEIN COMPOSITE GELS | 17 |
| 2.3.1 <i>Protein Source</i> | 17 |
| 2.3.2 <i>Protein Concentration</i> | 22 |
| 2.3.3 <i>Lipid Content</i> | 23 |
| 2.3.4 <i>pH</i> | 24 |
| 2.3.5 <i>Calcium Sequestering Agents (CSAs)</i> | 25 |
| 2.3.6 <i>Salt (NaCl) Concentration</i> | 27 |
| 2.3.7 <i>Lactose</i> | 27 |
| 2.3.8 <i>Processing</i> | 28 |
| 3.0 MATERIALS AND METHODS | 30 |
| 3.1 RAW MATERIALS | 30 |
| 3.2 PROCESSING OF MILK PROTEIN COMPOSITE GELS | 31 |
| 3.2.1 <i>Processing Equipment</i> | 31 |
| 3.2.2 <i>Processing Method</i> | 31 |

| | | |
|---------------------|--|------------|
| 3.3 | ANALYSIS METHODS FOR MILK PROTEIN COMPOSITE GELS | 32 |
| 3.3.1 | <i>Rheological Analysis</i> | 32 |
| 3.3.2 | <i>Chemical Analyses</i> | 35 |
| 3.3.3 | <i>Determination of Microstructure</i> | 37 |
| 3.3.4 | <i>Meltability</i> | 38 |
| 4.0 | RESULTS AND DISCUSSION..... | 39 |
| 4.1 | CHEMICAL ANALYSIS | 39 |
| 4.2 | MICROSTRUCTURE..... | 43 |
| 4.2.1 | <i>Rennet Casein</i> | 45 |
| 4.2.2 | <i>Skim Milk Cheese</i> | 51 |
| 4.2.3 | <i>Milk Protein Concentrate 85</i> | 56 |
| 4.2.4 | <i>Ion-Exchanged Milk Protein Concentrate 85</i> | 62 |
| 4.3 | LARGE STRAIN RHEOLOGY | 65 |
| 4.3.1 | <i>Statistical Analysis Issues</i> | 65 |
| 4.3.2 | <i>Rennet Casein</i> | 67 |
| 4.3.3 | <i>Skim Milk Cheese</i> | 71 |
| 4.3.4 | <i>Milk Protein Concentrate 85</i> | 74 |
| 4.3.5 | <i>Ion-Exchanged Milk Protein Concentrate 85</i> | 77 |
| 4.3.6 | <i>Comparison Between Protein Sources</i> | 80 |
| 4.4 | SMALL STRAIN RHEOLOGY | 87 |
| 4.4.1 | <i>Comparison Between Proteins</i> | 90 |
| 4.5 | TEMPERATURE DEPENDENCE | 96 |
| 4.5.1 | <i>Comparison Between Protein Sources</i> | 99 |
| 5.0 | CONCLUSIONS..... | 104 |
| 6.0 | RECOMMENDATIONS FOR FUTURE WORK..... | 106 |
| | REFERENCES..... | 108 |
| APPENDIX 1.0 | COMPRESSION TESTING SOFTWARE | 122 |
| APPENDIX 2.0 | MANUFACTURING EQUIPMENT COMPARISON..... | 123 |
| | SUMMARY | 123 |
| | INTRODUCTION | 123 |
| | MATERIALS AND METHODS | 123 |
| | <i>Processing Equipment</i> | 123 |
| | <i>Sample Testing and Data Analysis</i> | 126 |
| | RESULTS AND DISCUSSION | 127 |
| | <i>Fracture Properties</i> | 127 |
| | <i>Microstructure</i> | 128 |

| | |
|---|------------|
| <i>Manufacturing Problems</i> | 128 |
| APPENDIX 3.0 TA-XT2 AND INSTRON COMPARISON | 129 |
| SUMMARY | 129 |
| INTRODUCTION | 129 |
| MATERIALS AND METHODS | 129 |
| <i>TA-XT2 Texture Analyser Method</i> | 130 |
| <i>Instron Universal Testing Machine Method</i> | 131 |
| <i>Mixed Method</i> | 131 |
| <i>Data Analysis</i> | 131 |
| RESULTS AND DISCUSSION | 133 |
| <i>Texture Profile Analysis (TPA)</i> | 133 |
| <i>Fracture Analysis</i> | 134 |
| APPENDIX 4.0 TA-XT2 AND TA-HD COMPARISON | 136 |
| SUMMARY | 136 |
| MATERIALS AND METHODS | 136 |
| RESULTS AND DISCUSSION | 136 |
| APPENDIX 5.0 PROCESSING REGIME INVESTIGATION | 138 |
| SUMMARY | 138 |
| INTRODUCTION | 138 |
| METHODS AND MATERIALS | 138 |
| RESULTS AND DISCUSSION | 139 |
| APPENDIX 6.0 ADDITIONAL EXPLORATORY WORK | 141 |

LIST OF FIGURES

| | |
|---|----|
| FIGURE 2.1: MANUFACTURING PROCESSES FOR RENNET CASEIN, SMC, MPC 85 AND IX MPC 85 | 2 |
| FIGURE 2.2: APPLICATION OF STRESS TO SOLID MATERIAL..... | 6 |
| FIGURE 2.3: POSSIBLE FRACTURE MODES OF A CYLINDRICAL TEST PIECE DURING UNIAXIAL COMPRESSION..... | 7 |
| FIGURE 2.4: TPA CURVE FOR A MILK PROTEIN COMPOSITE GEL SAMPLE..... | 8 |
| FIGURE 2.5: TEXTURE PROFILE ANALYSIS OUTPUT INDICATING TPA PARAMETERS..... | 9 |
| FIGURE 2.6: COMPRESSION STRESS AS A FUNCTION OF HENCKY STRAIN | 10 |
| FIGURE 2.7: RESPONSE STRESS (σ) IN A MATERIAL WITH TIME WHEN AN OSCILLATING STRAIN IS APPLIED..... | 12 |
| FIGURE 2.8: PROPOSED INTERACTION BETWEEN WHEY PROTEINS AND RECOMBINED FAT GLOBULES IN MIXED AND FILLED DAIRY GELS..... | 20 |
| FIGURE 2.9: PROPOSED MECHANISMS OF INTERACTIONS BETWEEN LIPID DROPLETS AND PROTEIN MATRIX..... | 23 |
| FIGURE 2.10: EFFECT OF CALCIUM REMOVAL ON PROTEIN LINKAGES | 26 |
| FIGURE 3.1: TEMPERATURE PROFILE EXAMPLE FOR BLENTTECH COOKER | 32 |
| FIGURE 3.2: TA-HD TEXTURE ANALYSER..... | 34 |
| FIGURE 4.1: EFFECT OF CROSS SECTIONING AT DIFFERENT POINTS IN A FAT DROPLET OR AIR BUBBLE | 43 |
| FIGURE 4.2: CONFOCAL IMAGES OF RENNET CASEIN COMPOSITE GELS (P/W 0.4, 0.5 AND 0.6) WITH INCREASING PROCESSING TIME (400X MAGNIFICATION)..... | 47 |
| FIGURE 4.3: TEM OF RENNET CASEIN COMPOSITE GELS (P/W 0.4 & 0.6) AT 8-MINUTES PROCESSING TIME..... | 47 |
| FIGURE 4.4: TEM IMAGE (85 000X) OF A CASEIN MICELLE..... | 48 |
| FIGURE 4.5: CONFOCAL IMAGES OF SMC COMPOSITE GELS (P/W 0.4, 0.5 AND 0.6) WITH PROCESSING TIME (400X MAGNIFICATION) | 52 |
| FIGURE 4.6: TEM OF SMC COMPOSITE GELS (P/W 0.4 & 0.6) AT 8-MINUTES PROCESSING TIME | 52 |
| FIGURE 4.7: ENLARGED TEM IMAGE OF SMC ILLUSTRATING THE PRESENCE OF ELECTRON-DENSE "STRANDS" ... | 54 |
| FIGURE 4.8: CONFOCAL IMAGE OF MPC 85 COMPOSITE GELS (P/W 0.4, 0.5 & 0.6) WITH INCREASING PROCESSING TIME (400X MAGNIFICATION)..... | 58 |
| FIGURE 4.9: TEM OF MPC 85 COMPOSITE GELS (P/W 0.4 & 0.6) AT 8-MINUTE PROCESSING TIME..... | 58 |
| FIGURE 4.10: CONFOCAL IMAGES OF IX MPC 85 COMPOSITE GELS (P/W 0.4, 0.5 & 0.6) WITH PROCESSING TIME (400X MAGNIFICATION) | 63 |
| FIGURE 4.11: TEM OF IX MPC 85 COMPOSITE GELS (P/W 0.40) AT 8-MINUTES PROCESSING TIME | 63 |
| FIGURE 4.12: FRACTURE STRESS AND FRACTURE STRAIN FOR RENNET CASEIN COMPOSITE GEL SAMPLES..... | 67 |
| FIGURE 4.13: FRACTURE STRESS AND FRACTURE STRAIN FOR SMC COMPOSITE GEL SAMPLES | 72 |
| FIGURE 4.14: FRACTURE STRESS AND FRACTURE STRAIN FOR MPC 85 COMPOSITE GEL SAMPLES..... | 74 |
| FIGURE 4.15: FRACTURE STRESS AND FRACTURE STRAIN FOR IX MPC 85 COMPOSITE GEL SAMPLES..... | 77 |
| FIGURE 4.16: INTERACTION PLOT FOR FRACTURE STRAIN | 81 |
| FIGURE 4.17: INTERACTION PLOT FOR FRACTURE STRESS..... | 82 |
| FIGURE 4.18: FRACTURE PROPERTIES OF SAMPLES FOR ALL PROTEIN SOURCES | 84 |
| FIGURE 4.19: INTERACTION PLOT FOR STORAGE MODULUS | 90 |
| FIGURE 4.20: INTERACTION PLOT FOR FREQUENCY DEPENDENCE (P-VALUE)..... | 91 |
| FIGURE 4.21: COMPARISONS OF LARGE-STRAIN AND SMALL-STRAIN HARDNESS PARAMETERS..... | 94 |

| | |
|---|-----|
| FIGURE 4.22: UW MELTMETER APPARATUS | 97 |
| FIGURE 4.23: INTERACTION PLOT FOR H_p/H_l | 99 |
| FIGURE 4.24: INTERACTION PLOT FOR G^* AT 45°C..... | 100 |
| FIGURE A2.1: LAB-SCALE BLENTECH CHEESE COOKER..... | 124 |
| FIGURE A2.2: LAB-SCALE STEPHAN CHEESE KETTLE..... | 125 |
| FIGURE A2.3: FRACTURE STRESS AND FRACTURE STRAIN FOR STEPHAN AND BLENTECH GELS..... | 127 |
| FIGURE A2.4: BLENTECH SAMPLES..... | 128 |
| FIGURE A2.5: STEPHAN SAMPLES | 128 |
| FIGURE A5.1: FRACTURE PROPERTIES OF RENNET CASEIN AND MPC SAMPLES..... | 139 |

LIST OF TABLES

| | |
|---|-----|
| TABLE 1: PROTEIN SOURCES FOR MPCG MANUFACTURE | 17 |
| TABLE 2: COMPOSITION OF PROTEIN SOURCES | 30 |
| TABLE 3: CHEMICAL COMPOSITION OF SAMPLES (DUPLICATES AVERAGED EXCEPT SMC P/W 0.5 AND 0.6)..... | 42 |
| TABLE 4: NON-NORMAL DATA SETS..... | 65 |
| TABLE 5: FRACTURE PROPERTIES FOR RENNET CASEIN COMPOSITE GEL SAMPLES | 68 |
| TABLE 6: FRACTURE PROPERTIES OF SMC COMPOSITE GEL SAMPLE..... | 72 |
| TABLE 7: FRACTURE PROPERTIES OF MPC 85 COMPOSITE GEL SAMPLES | 75 |
| TABLE 8: FRACTURE PROPERTIES OF IX MPC 85 COMPOSITE GEL SAMPLES | 78 |
| TABLE 9: FRACTURE STRESS AND FRACTURE STRAIN FOR ALL PROTEIN SOURCES..... | 84 |
| TABLE 10: SMALL-STRAIN PROPERTIES OF COMPOSITE GELS SAMPLES..... | 88 |
| TABLE 14: SMALL-STRAIN PROPERTIES OF SAMPLES FOR ALL PROTEINS SOURCES | 92 |
| TABLE 15: REGRESSION COEFFICIENTS FOR FRACTURE STRESS AND STORAGE MODULUS | 94 |
| TABLE 16: MELT PROPERTY TRENDS WITH INCREASING PROCESSING TIME FOR ALL PROTEIN SOURCE SAMPLES ... | 97 |
| TABLE 17: MELTABILITY VALUES FOR SMALL-STRAIN AND UW MELTMETER METHODS OF SAMPLES FOR ALL PROTEIN SOURCES..... | 102 |
| TABLE 18: FORMULATIONS FOR BLENTECH CHEESE COOKER..... | 124 |
| TABLE 19: FORMULATIONS FOR STEPHAN CHEESE COOKER | 125 |
| TABLE 20: P/W VARIATION IN SAMPLES | 127 |
| TABLE 21: FORMULATION FOR TEXTURE ANALYSIS METHOD COMPARISON..... | 130 |
| TABLE 22: HARDNESS VALUES AT FULL COMPRESSION..... | 133 |
| TABLE 23: FRACTURE PROPERTIES FOR COMPRESSION METHOD COMPARISON..... | 134 |
| TABLE 24: FRACTURE PROPERTIES FOR TA-XT2 AND TA-HD..... | 137 |
| TABLE 25: PROCESSING FORMULATIONS..... | 138 |

LIST OF EQUATIONS

| | |
|--|----|
| EQUATION 2.1: NORMAL STRAIN CALCULATION..... | 6 |
| EQUATION 2.2: TANGENTIAL STRAIN CALCULATION..... | 6 |
| EQUATION 2.3: HENCKY STRAIN..... | 10 |
| EQUATION 2.4: TRUE STRESS..... | 10 |
| EQUATION 2.5: DETERMINATION OF STORAGE MODULUS..... | 12 |
| EQUATION 2.6: DETERMINATION OF LOSS MODULUS | 13 |
| EQUATION 2.7: DETERMINATION OF COMPLEX MODULUS | 13 |
| EQUATION 2.8: FREQUENCY DEPENDENCE OF THE STORAGE MODULUS..... | 13 |
| EQUATION 2.9: LINEAR RELATIONSHIP BETWEEN STORAGE MODULUS AND FREQUENCY..... | 13 |
| EQUATION 3.1: CALCULATION OF STORAGE MODULUS | 33 |
| EQUATION 3.2: CALCULATION OF LOSS MODULUS..... | 33 |
| EQUATION 3.3: CALCULATION OF COMPLEX MODULUS..... | 33 |
| EQUATION 4.1: HENCKY STRAIN..... | 71 |

NOMENCLATURE

| | | |
|-----------------------|--|------------------------|
| ℓ | Length (mm) | (Rheology) |
| $\delta\ell$ | Change in length (mm) | (Rheology) |
| ε | Strain (-) | (Rheology, normal) |
| σ | Stress (Pa) | (Rheology, normal) |
| γ | Shear strain (-) | (Rheology, tangential) |
| τ | Shear stress (Pa) | (Rheology, tangential) |
| H | Sample height at any time (mm) | (Compression testing) |
| H_0 | Initial sample height (mm) | (Compression testing) |
| Δh_t | Displacement of crosshead at time t (mm) | (Compression testing) |
| v | Speed of compression (mm s^{-1}) | (Compression testing) |
| F_t | Force during lubricated compression at time t (N) | (Compression testing) |
| r_0 | Initial radius of sample (m) | (Compression testing) |
| σ_{\max} | Maximum stress (Pa) | (Compression testing) |
| σ_{∞} | Infinite stress (Pa) | (Compression testing) |
| $\dot{\varepsilon}_0$ | Initial strain rate (s^{-1}) | (Compression testing) |
| ε_{\max} | Maximum strain (-) | (Compression testing) |
| ε_c | Cauchy strain (-) | (Compression testing) |
| ε_H | Hencky strain (-) | (Compression testing) |

| | | |
|----------------|---------------------------------------|------------------------|
| σ_o | Maximum stress (Pa) | (Oscillatory rheology) |
| γ_o | Maximum strain (-) | (Oscillatory rheology) |
| $\sigma_{el.}$ | Elastic material reaction stress (Pa) | (Oscillatory rheology) |
| $\sigma_v.$ | Viscous material reaction stress (Pa) | (Oscillatory rheology) |
| $\dot{\gamma}$ | Strain rate/Shear rate (s^{-1}) | (Oscillatory rheology) |
| G' | Storage modulus (Pa) | (Oscillatory rheology) |
| G'' | Loss modulus (Pa) | (Oscillatory rheology) |
| G^* | Complex modulus (Pa) | (Oscillatory rheology) |
| G^*_{min} | Minimum complex modulus (Pa) | (Oscillatory rheology) |
| δ | Phase angle ($^\circ$) | (Oscillatory rheology) |
| $\tan \delta$ | Loss tangent | (Oscillatory rheology) |
| ω | Oscillation frequency (Hz) | (Oscillatory rheology) |
| η^* | Apparent viscosity | (Oscillatory rheology) |

ABBREVIATIONS

| | |
|-----------|--|
| AMF | Anhydrous milk fat |
| Ca | Calcium |
| C/P ratio | Calcium to protein ratio |
| CSA | Calcium sequestering agent |
| DSP | Disodium phosphate |
| EMC | Enzyme modified cheese |
| FRC | Fonterra Research Centre Limited |
| FTRC | Food Technology Research Centre |
| HPLC | High-performance liquid chromatography |
| IX MPC | Ion-exchanged MPC (calcium depleted) |
| MPC | Milk protein concentrate |
| MPCG | Milk protein composite gel |
| Na | Sodium |
| NaCl | Sodium chloride |
| NCN | Non-casein nitrogen |
| NPN | Non-protein nitrogen |
| NZDRI | New Zealand Dairy Research Institute |
| P/W ratio | Protein to water ratio |
| SALP | Sodium aluminium phosphate |
| SMC | Skim milk cheese |

| | |
|-----|----------------------------------|
| SMP | Skim milk powder |
| TEM | Transmission electron microscopy |
| TMP | Total milk protein |
| TN | Total nitrogen |
| TPA | Texture profile analysis |
| TSC | Trisodium citrate |
| TSP | Trisodium phosphate |
| WPC | Whey protein concentrate |
| WPI | Whey protein isolate |

A copy of the Nomenclature and Abbreviations is given in a fold-out format at the back of this thesis.

1.0 INTRODUCTION

Milk protein composite gels (MPCGs) can be formed directly from milk, by recombining milk protein powders or via roux¹ formation with fat and milk protein powders. The two latter methods of forming milk protein gels are extremely versatile and products can be made to resemble a soft mousse-like product through to a hard cheese-like product through manipulation of the composition and processing methods (Saunders *et al.*, 1996c). These adaptable gels can be manufactured from a large range of stable intermediate protein products, such as Rennet Casein, milk protein concentrates (MPCs), calcium-depleted milk protein concentrates (IX MPCs²), skim milk powder, skim milk cheese (SMC) powder, sodium caseinate and calcium caseinate. These protein products influence the final flavour and texture of the product. The water content, amount and type of lipid, flavour and processing conditions can also be varied to produce a range of end products. Other ingredients may be used to influence texture and flavour, such as calcium chelating agents, salts, hydrocolloids, starches, enzyme modified cheese (EMC) and commercial flavour compounds.

Although milk protein gel products have been produced both commercially and for research purposes, the work has generally focused on emulating an existing product or investigating processed cheese. There has been little systematic work done to understand the chemical and physical interactions that affect the characteristics of the final product.

Composition, pH, shear, temperature, time, salt, emulsifiers, protein source, lipid, mixer design, mixing speed, cooling rate, order of addition, rate of addition, pH, acid type and level and the interactions between each of these affect the characteristics of the final product.

Increased knowledge of the mechanisms and outcomes of these interactions is essential for the further development of dairy-based analogue products and the advancement of novel product development (Saunders *et al.*, 1996c; Thompson and Hewitt, 2000). The work described in this thesis focuses on the effects of protein source, protein concentration and processing time on the product characteristics of recombined milk protein gels.

¹ Mixture of fat and protein powder

² IX MPCs are MPCs that are calcium depleted by ion exchange (IX)