QUALITY WHEAT CRC PROJECT REPORT

Project 5.2.1: University based education

Vacation Scholarships 1998/99 Summer Student Reports

Compiled by: Clare Johnson

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QWCRC Report No: 26
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Quality Wheat CRC
Vacation Scholarships 1998/99

Clare Johnson & Les Copeland

The projects run this year were:

	Student	Project	Supervisor
1	Bradley Schultz	Portable Automatic Bread Weighing Machine and Weight Tracking System for Commercial Bakeries	T. Adamczak, BRI Australia Ltd
2	Ayla Pelit	Texture Analysis of Baked Products	D. Miskelly, Goodman Fielder
3	David Appels	The Effects of Freezing on Noodle Quality, and Determining Factors	N. Azudin, Agrifood Technology
4	Wendy Leung	Investigation of biaxial stretching of bread dough: (a) Effects of Lubrication in Biaxial Extension Measurements; (b) Computer Simulation of Squeeze Film Flow	R. Tanner, Mechanical Engineering, University of Sydney
5	Keith Leong	(a) Dough Rheology of Heat Treated Flours (b) High Speed Dough Tester Trial	E. Hocking, Weston Food Laboratories, Enfield
6&7	Vanessa Yu and Kate McDonald (Combined)	WheatRite: (a) Analysis of within- and between Paddock Variation in Sprouting (b) Suitability of WheatRite Test to Monitor Pre-harvest Sprouting in Barley (c) Assessing grower responses to a new test for pre-harvest sprouting	J. Skerritt, R Heywood, CSIRO Plant Industry
8	Chris Moore	Breeding Soft Biscuit Wheats for the Northern Wheatbelt	Lindsay O'Brien, I.A. Watson Grains Research Centre, Narrabri

Excellent reports were received from the students.
These have been compiled in the pages which follow.

Identification of Projects:
In response to a call for projects sent in July to all CRC participants, 17 proposals were received. These included projects from Goodman Fielder Milling and Baking Technical Centre; the Departments of Mechanical and Mechatronic Engineering and Agricultural Chemistry and Soil Science and the I.A. Watson Grains Research Centre in the University of Sydney; CSIRO Plant Industry, Canberra and North Ryde; BRI Australia Ltd; Agrifood Technology, Werribee; Weston Food Laboratories, Enfield; School of Public Health, Curtin University; NSW Agriculture, Wagga Wagga. Of these, five could be funded by the CRC's Education Program.

Notices on the Summer Vacation Scholarships were sent in mid-September to universities along the Eastern seaboard, as well as to Southern Cross University, Victoria University of Technology, University of Queensland, University of Southern Queensland, Curtin and Murdoch Universities.

Selection procedure:
We received 32 applications for 17 project proposals in total, and in addition to the 5 scholarships available through the budget, an additional two projects became available as repayment of staffing commitment by CSIRO Plant Industry, and one from Lindsay O'Brien's project funding. Thus, a total of 8 students obtained a place.

Students were asked to state their project preferences in their application. Then, balancing allocation of projects between organisations, the field was narrowed on the basis of the students' ability. The aim was to provide supervisors of the resulting projects with a choice between several promising students. Supervisors at BRI decided which of their projects should be pursued, based on student aptitude.

Resumes of at least the 3 top applicants for each scholarship were sent to the relevant supervisors for final selection. Those who had submitted projects were notified of the outcome on November 5.

Reserve project:
- DNA markers linked to stem rust and *Septoria tritici* blotch resistance genes in wheat (NSW Agriculture).

Due to budget limitations, this could not be run despite there being good applicants available. An increase in the number of studentships available will be recommended for next year's budget, to improve opportunities available to all Participants.

Followup:
Accompanying the offer of the scholarship, each student was provided with an annual report and brochure on QWCRC to encourage their interest in the wheat industry. All applicants from this and past years were also provided with this information, and were encouraged to write in at the start of their final year of study, to try to negotiate provision of a postgraduate or Honours scholarship in the CRC budget.

Bradley Schultz

Portable Automatic Bread Weighing Machine and Weight Tracking System for Commercial Bakeries

Supervisor: T. Adamczak, BRI Australia Ltd

Interim Report

CRC Wheat Research Vacation Scholarship
Progress Report

Project:	Quality Wheat CRC Project 3.4.2
Student:	Bradley Schultz
Location:	BRI Australia Limited.
Supervisor:	Thomas Adamczak
Commenced:	14/12/1998
Proposed Completion:	26/2/1999

INTRODUCTION:

Weight loss of loaves of bread during the baking process is a variable of great interest. Measuring weight loss is quite a difficult process, especially since most bakeries do not have on-line weighing mechanisms in place to weigh the baked product.

WEIGHT TAKING MACHINE:

Work during the vacation scholarship has focused on the development of a 'Weight Taking Machine'. This machine has been designed to be placed next to a conveyor belt carrying bread that has just been removed from the tray. It will remove a loaf of bread from a conveyor, weigh it, then replace the loaf. The weight, bread count and other variables are logged in a computer file. The weight loss during baking may be determined using this data in conjunction with some data collected from existing baking dough dividing equipment.

WORK COMPLETED:

Currently, the software for controlling the machine has been developed using the 'Think' n' Do' software package from PLCDirect™. The machine has been designed and constructed. Some initial testing has been completed.

FURTHER WORK:

Further work to be done includes complete testing of the machine and finishing construction so that it is suitable for industrial use. The machine will then be put to use at a bakery in Brisbane where data will be collected with a view to see how well the baking process is operating.

OTHER WORK:

Other work during the vacation scholarship has involved a data-collecting trip to a bakery in Canberra involving the setup and operation of equipment to log information about the baking process. Post-processing of the data obtained was performed to yield meaningful results. Also, colour-monitoring equipment has been set up at a bakery at Liverpool logging the colour of passing buns.

B.J. Schultz

Student, Bradley Schultz

T. Adamczak

Supervisor, Thomas Adamczak

Bradley Schultz

Portable Automatic Bread Weighing Machine and Weight Tracking System for Commercial Bakeries

Supervisor: T. Adamczak, BRI Australia Ltd

Final Report

Introduction

The CRC Wheat Research Vacation Scholarship involved several major interrelated projects. These are discussed below.

Portable Automatic Bread Weighing Machine

The portable automatic bread weighing machine was designed to remove a loaf of bread from a conveyor, weigh it, log its weight, then return it to the conveyor. This is achieved through the use of pneumatics and computer control.

The hardware was designed and constructed and software written to control the machine. Preliminary tests were then done at a local bakery in Sydney. Further extensive testing was carried out in Brisbane. Several modifications need to be made before the machine may be used for long periods unsupervised.

Future uses for the machine may include measuring core temperature and taking digital photographs of loaves of bread.

A picture of the machine operating can be seen below.

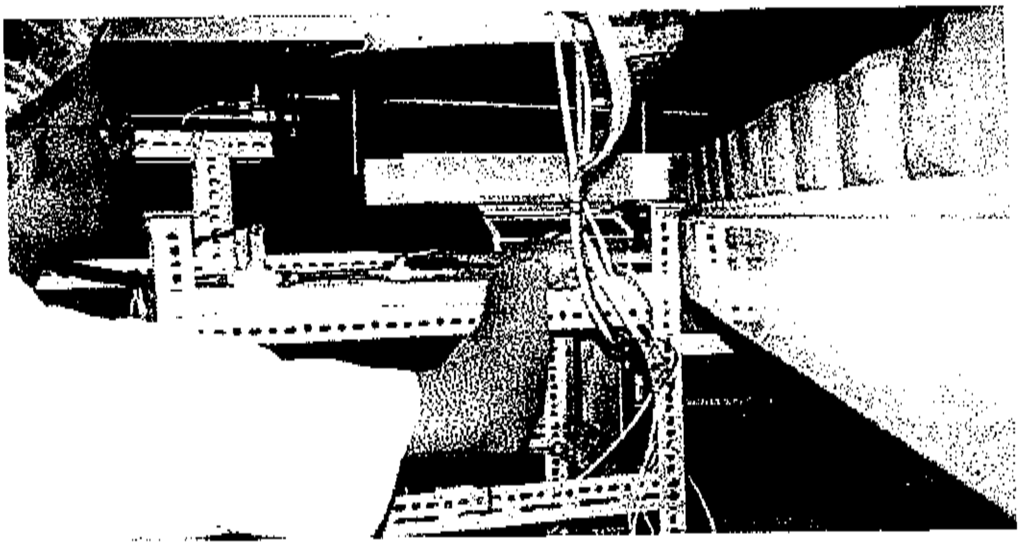


Figure 1

Weight Tracking System

Software was developed to track products moving through a bakery. It operated by taking inputs from proximity sensors that sensed the product passing by. This software was used at two bakeries to help investigate bakery operation. When combined with weight data, useful plots that show beginning/final weights and weight loss may be produced. An example is shown below (Figure 2).

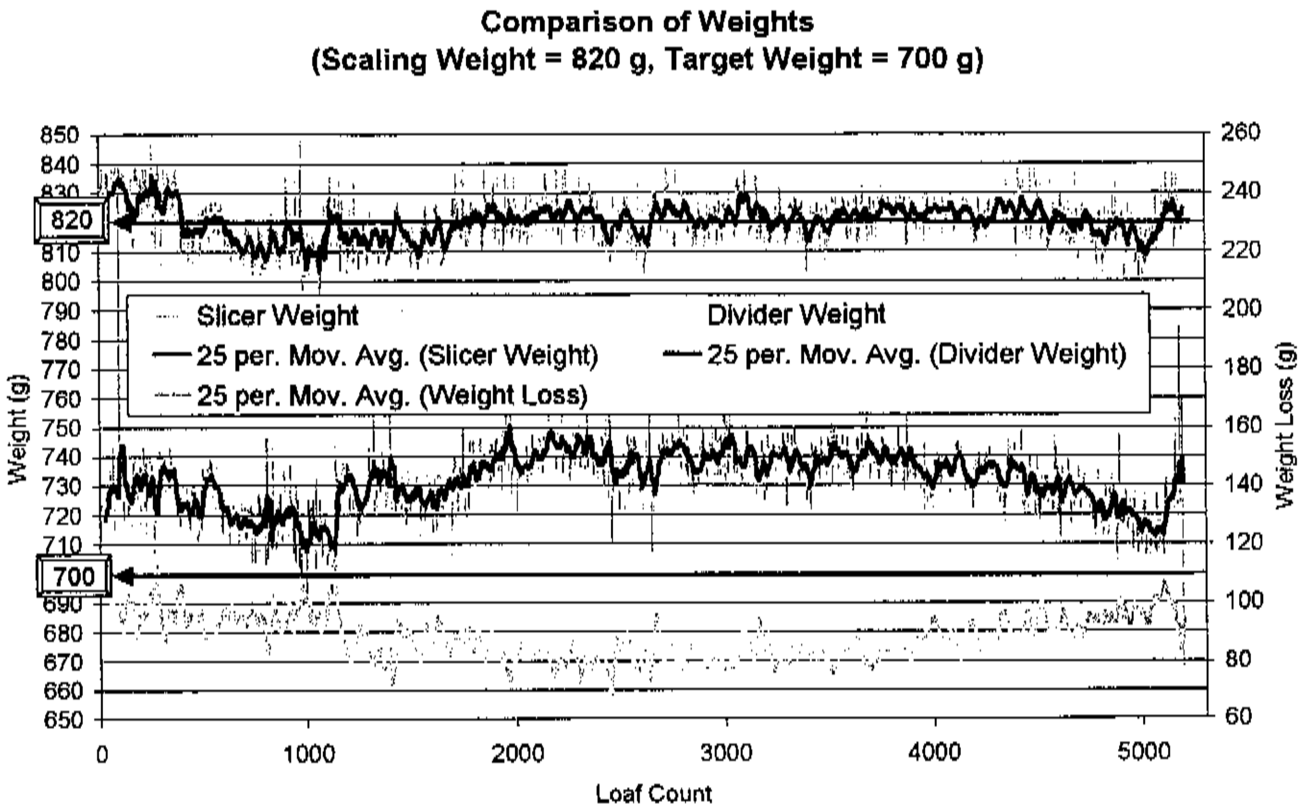


Figure 2

Information such as that above was then combined with other data such as height, colour and temperature measurements to give useful information on how well the bakery was operating.

Summary:

The projects undertaken during the CRC Wheat Research Scholarship were part of a much larger project that has the aim of providing a control system for an entire bakery. The projects were successful and will hopefully play a part in ensuring the success of the bakery control project.

Ayla Pelit

Texture Analysis of Baked Products

Supervisor: D. Miskelly, Goodman Fielder

Interim Report

QWCRC UNDERGRADUATE VACATION SCHOLARSHIP
PROGRESS REPORT

Texture Analysis of Dough and Baked Products

Student Name:	Ayla Pelit
	University of Sydney
	BE (Chem.) Year 3
Company:	Goodman Fielder - Summer Hill
Supervisor:	Di Miskelly
Date commenced:	07/12/98

The aim of this project is to investigate the methods used for textural analysis of the various attributes of bread, and to determine standard method(s) for these characteristics.

Initially a research plan was formulated and a literature search was carried out in order to summarize the main findings and tabulate test conditions for comparison. In conclusion of the literature review, softness was found to be the most commonly measured textural property of bread. Background reading on the chemical and physical properties of bread, bread baking and texture was also found to contribute to an overall understanding of the project aim.

The various mixers used in dough making were introduced and the bread baking method for straight molded and four-piece bread was learnt in the test bakery. This method was used to produce bread for initial texture experiments.

The SMS TA.XT2 Texture Analyser was explored in terms of operation and programming in order to gain familiarity with the available tests and the set-up of projects.

The SMS TA.XT2 Texture Analyser was employed to carry out preliminary texture trials on straight and four-piece molded bread produced in the test bakery, using two methods of analysis. The first being the current GF method and the second the AACC % strain method.

The next stage in the project is to analyze the results obtained from the comparative texture experiments on the bread produced in the test bakery, and apply the "best" method for analysis to commercial bread.

I also had the opportunity to gain experience in other project areas such as running particle sizing tests on the Malvern Mastersizer for commercial flours. A tour of the Summer Hill Mill was attended which provided an insight into the processing of wheat and production of flour.

Ayla Pelit

Texture Analysis of Baked Products

Supervisor: D. Miskelly, Goodman Fielder

Final Report

QWCRC UNDERGRADUATE VACATION SCHOLARSHIP
FINAL REPORT

Texture Analysis of Baked Products

Student Name:	Ayla Pelit
	University of Sydney
	BE (Chem.) Year 3
Company:	Goodman Fielder - Summer Hill
Supervisor:	Di Miskelly
Date commenced:	07/12/98
Date completed:	22/2/99

The aim of this project was to investigate the methods used for textural analysis of the various attributes of bread, and to determine standard method(s) for these characteristics.

The SMS TA.XT2 Texture Analyser was employed to carry out preliminary texture trials on straight and four-piece molded bread produced in the test bakery, using two methods of analysis. The first was compression to a standard distance and the second the AACC % strain method. The effect of reusing samples for testing was also investigated.

The firmness profile throughout the loaves on Day 1 for straight moulded bread produced in the test bakery is represented in Figure 1.

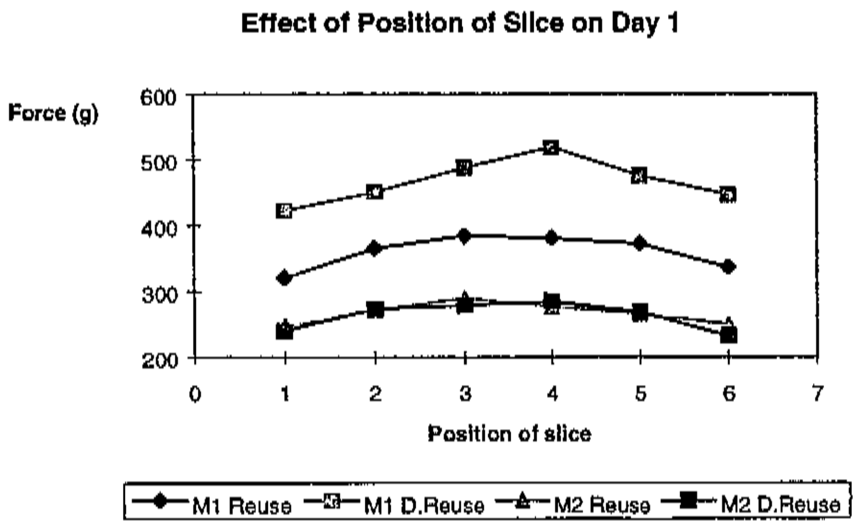


Figure 1: Demonstrates the profile of firmness throughout the loaves on Day 1 for the different methods. M1 = Method 1, M2 = Method 2, D.Reuse = Don't reuse

The effect of slice position on the force measured for four-piece moulded bread produced in the test bakery is shown in Figure 2.

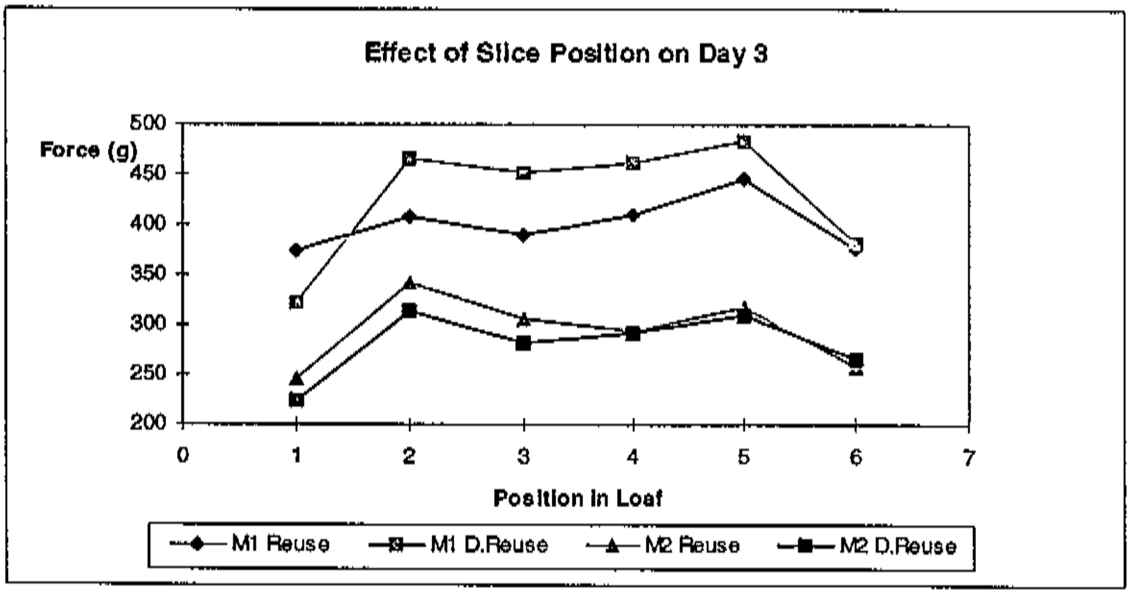


Figure 2: Demonstrates the difference in firmness for slices in different positions throughout the loaf for four-piece moulded test bread. This graph is a representation of the firmness profile throughout the loaves tested by the two methods on Day 3.

The two methods were then incorporated into Texture Profile Analysis (TPA) in order to perform tests on commercial bread. Three trials were carried out on commercial bread, two of which investigated the firmness of bread and one which examined a method of measuring bread toughness.

The first trial aimed to determine the variation of firmness throughout loaves for a population of 30 loaves over a testing period of one week. There was found to be significant variation between loaves, with the coefficient of variation determined at 15%.

The second trial that examined the firmness of commercial bread, also aimed to investigate any existing correlations between TPA parameters. Most parameters were found to be highly correlated with each other. Therefore it is concluded that no extra information is gained by performing texture profile analysis over and above a simple compression test. Table 1 shows the results of the Pearson Correlation matrix.

Table 1: *Pearson Correlation* matrix results performed on commercial four-piece moulded bread.

	Force 1	*Force 2*	*Adhesiveness*	*Springiness*	*Cohesiveness*	*Chewiness*
Force 2						
Adhesiveness	0.54	0.54				
Springiness	-0.21	-0.21	-0.19			
Cohesiveness	-0.89	-0.88	-0.46	0.20		
Chewiness	0.80	0.80	0.44	0.06	-0.67	
Resilience	-0.88	-0.88	-0.39	0.21	0.89	-0.689

Using the Kramer Shear cell the toughness of commercial bread was investigated. However, the results obtained indicated the need of additional tests to be performed since the force measured via this method could not be confirmed to be "toughness".

Both Method 1 and Method 2 gave acceptable results but Method 2, the Standard AACC method is preferred since it is a standard method and has already been published.

David Appels

The Effects of Freezing on Noodle Quality, and Determining Factors

Supervisor: N. Azudin, Agrifood Technology

Final Report

&

The effects of freezing on noodle quality, and determining factors.

Worked performed by David Appels at Agrifood Technology,
funded by the Quality Wheat CRC, for Dr Nasir Azudin

To date, there has been a limited amount of focus on frozen noodle products. This summer scholarship project is aimed at investigating the factors which influence noodle quality upon freezing. These aspects include properties of the flour used, as well as freezing and noodle-making protocols. The key factors currently being considered are:

- Rate of freezing
- Sample size
- Sample packaging
- Protein (starch) levels of flour
- Starch paste viscosity values of flour
- Salt content of noodle
- Water content of noodle
- Freezing after varying degrees of cooking
- Freeze / Thaw stability

Before these elements could be explored, the procedure for noodle preparation had to be established. This was learnt through a week of noodle making with trial flour samples for the VIDA laboratories in Horsham. This involved extensive udon, yellow alkaline and instant noodle making. From this, the following procedure was adopted for raw noodle preparation:

Udon	Yellow Alkaline

200 g flour + 74 g solution, or 250 g flour + 92.5 g solution

Udon	Yellow Alkaline
solution: 3% water 2% NaCl	solution: 35% water 1% NaCl 1% alkaline salts (4:6 , Na_2CO_3:K_2CO_3)
mixing: 1 minute on 1 2 minutes on 2	mixing: 1 minute on 1 4 minutes on 2

↓

press crumbs into sheet, then roll dough sheet at 3.0 mm

Udon	Yellow Alkaline
rolling: fold in 3 - roll fold in 2 - roll fold in 2 - roll	rolling: fold in 3 - roll fold in 2 - roll

↓

Rest dough sheet for 30 minutes

Udon	Yellow Alkaline
rolling: through 2.5 mm rollers -check thickness -correct so that resultant sheet is 2.5 mm in thickness	rolling: through 2.1 mm rollers through 1.5 mm rollers -check thickness -correct so that resultant sheet is 1.5 mm in thickness
roll and cut using large noodle cutter	roll and cut using small noodle cutter

↓

Raw noodle product

Udon	Yellow Alkaline
cooked in boiling water for 20 minutes	cooked in boiling water for 5 minutes

↓

cooking process quenched in cold water and noodles drained

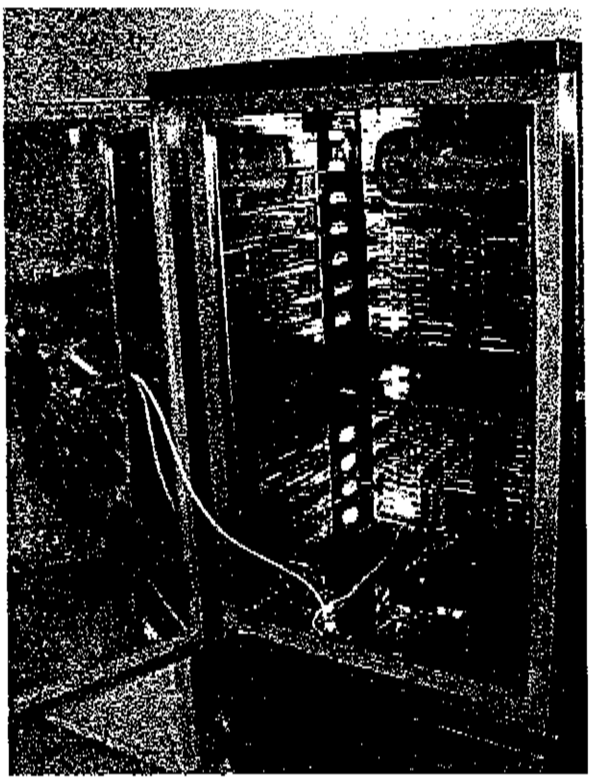
↓

Cooked noodle product

The machine used for sheeting and cutting the dough samples has been imported from Japan and is the only one of its kind currently in Australia:

A consistent method for the evaluation of noodle samples was also established. This involves the consideration of the following factors:

- appearance - assessed by subjective colour / brightness and surface definition
- textural changes - elasticity and firmness determined by a Lloyd texture analyser
- colour stability - using a Minolta colorimeter
- sensory testing - tasting to determine noodle mouth feel
- structural changes - by electron scanning microscopy
- exudate - weight of fresh noodle sample (before freezing) minus mass when thawed

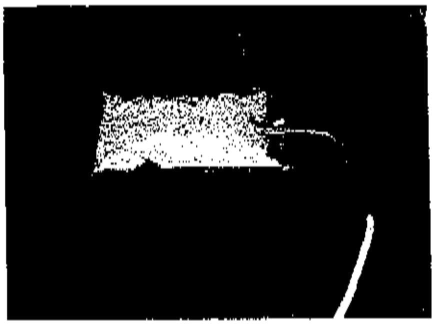


The IRINOX shock freezer is designed to reduce the temperature from + 70 °C to - 18 °C at product core within 4 hours, with chamber air temperature of - 40 °C. The fast chilling penetration speed is aimed at avoiding the formation of macro ice crystals. Since the noodle water content is microcrystallised, degradation of the product upon freezing should be reduced. The cooling process is convection driven, with two large fans in the unit (as seen on the illustration left) ensuring a high airflow over the noodle block surface.

A protocol for shock freezing of the noodle sample was ascertained by trials of freezing noodle samples. The following method was arrived at to ensure reproducibility and to maintain the condition of the IRINOX shock freezer.

1) Preparation of raw noodle.
2) Cooking (partial or complete) of noodle sample.
3) Complete washing with cold water of noodles, to remove most unincorporated surface starch, followed by thorough straining to dry product.
4) Weigh out desired sample size (control is 150 g) and heat seal into packaging.

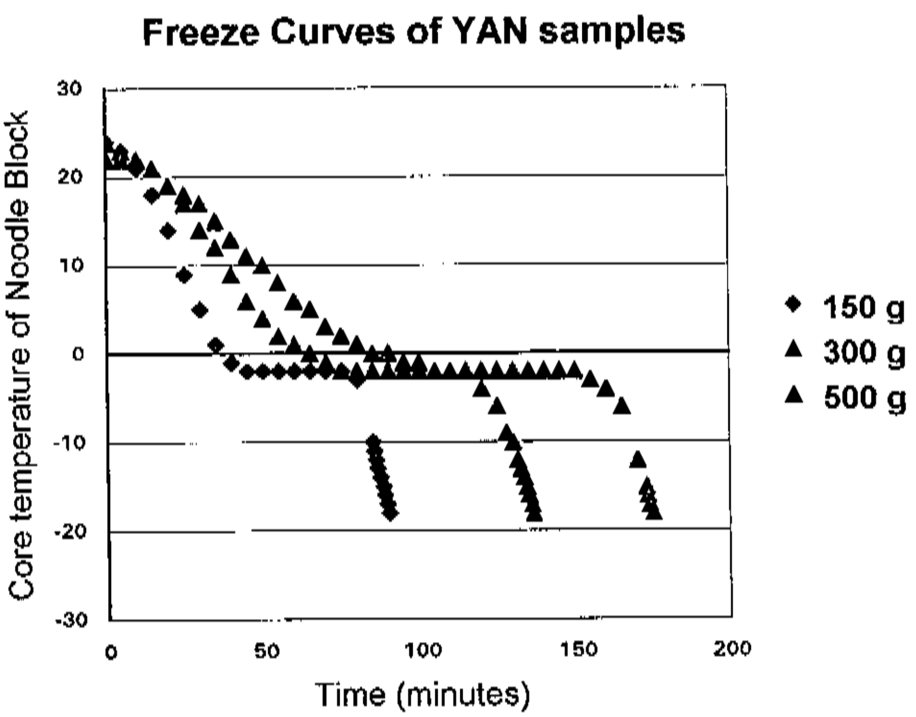
5) Insert probe sensor into centre of noodle block. (see below)



6) Place sample on central shelf (8th from top) and begin 'shock freezing' cycle, in IRINOX. Completion of cycle taken approximately 50 minutes, varying slightly on the initial temperature of the sample.
7) Immediate transferral to storage freezer after removal from IRINOX.
8) Defrost cycle takes about 20 minutes to restore cabinet temperature to room temperature. Wipe down inside if any condensation, and follow by a sterilisation cycle (30 minutes).

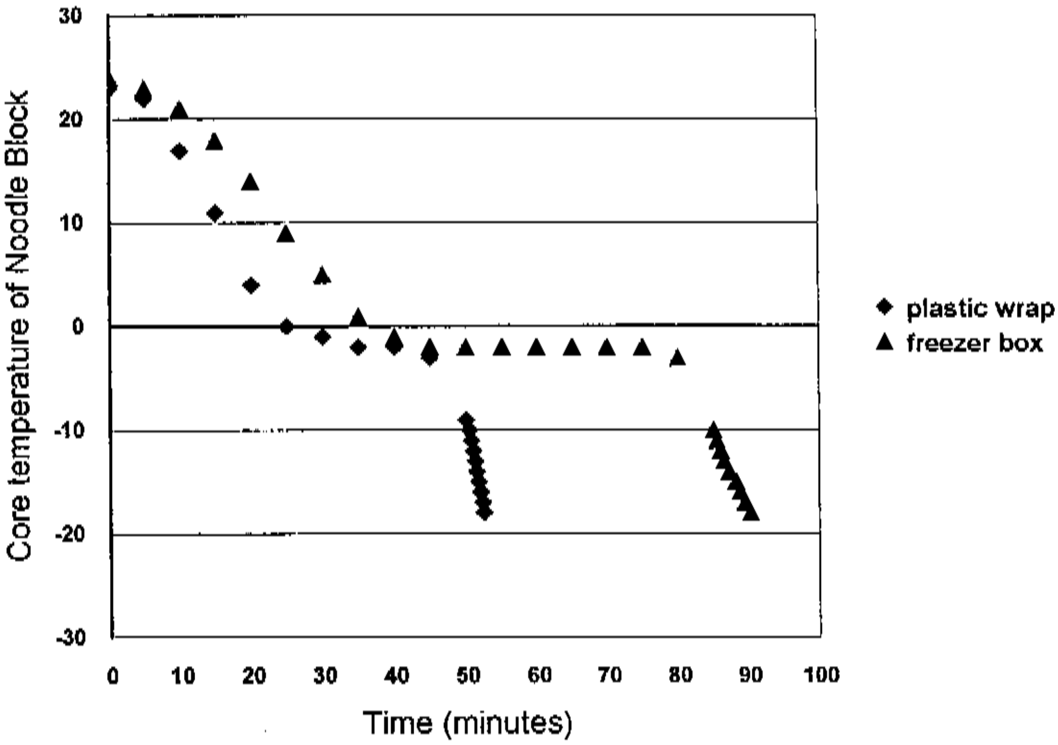
Using these methods, a number of freeze curves were generated to illustrate the effects of different noodle types, sample sizes and types of packaging. Included in the appendix to this report are the graphs representing the results. A number of interesting features and trends are apparent in these results.

- All the freeze curves have a flat section in the middle, at a temperature of just below zero degrees. This is the region of the curve during which the freezing of the water content in the noodle block is occurring, and is relatively flat since the core temperature of the block cannot fall further until the water in the entire sample has made the state transition from liquid to solid. The exact temperature of this flat region is determined by the salt content of the noodles, since this result in freezing point depression of the water present.
- The larger sample sizes resulted in longer freeze curves, as expected, presumably since the it takes more time for the thermal energy to permeate from the core through to the outside of a larger sample. Below is the comparison for yellow alkaline noodle samples:

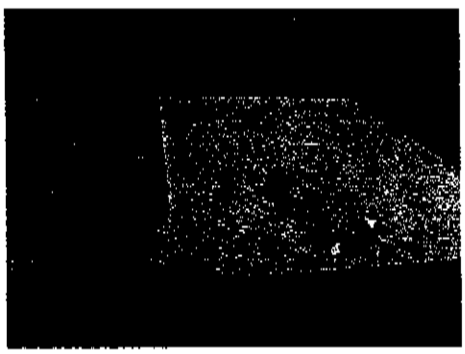


- Two different types of packaging for the noodle samples were used, freezer boxes and heat-sealing plastic bags. There was a considerable difference between the freezing times for samples in the different containers, indicating a more efficient transfer of heat in the case of the plastic bags and hence fast freeze rates. Below is the comparison for yellow alkaline noodle samples:

Freeze Curves of 150 g YAN samples in various packaging



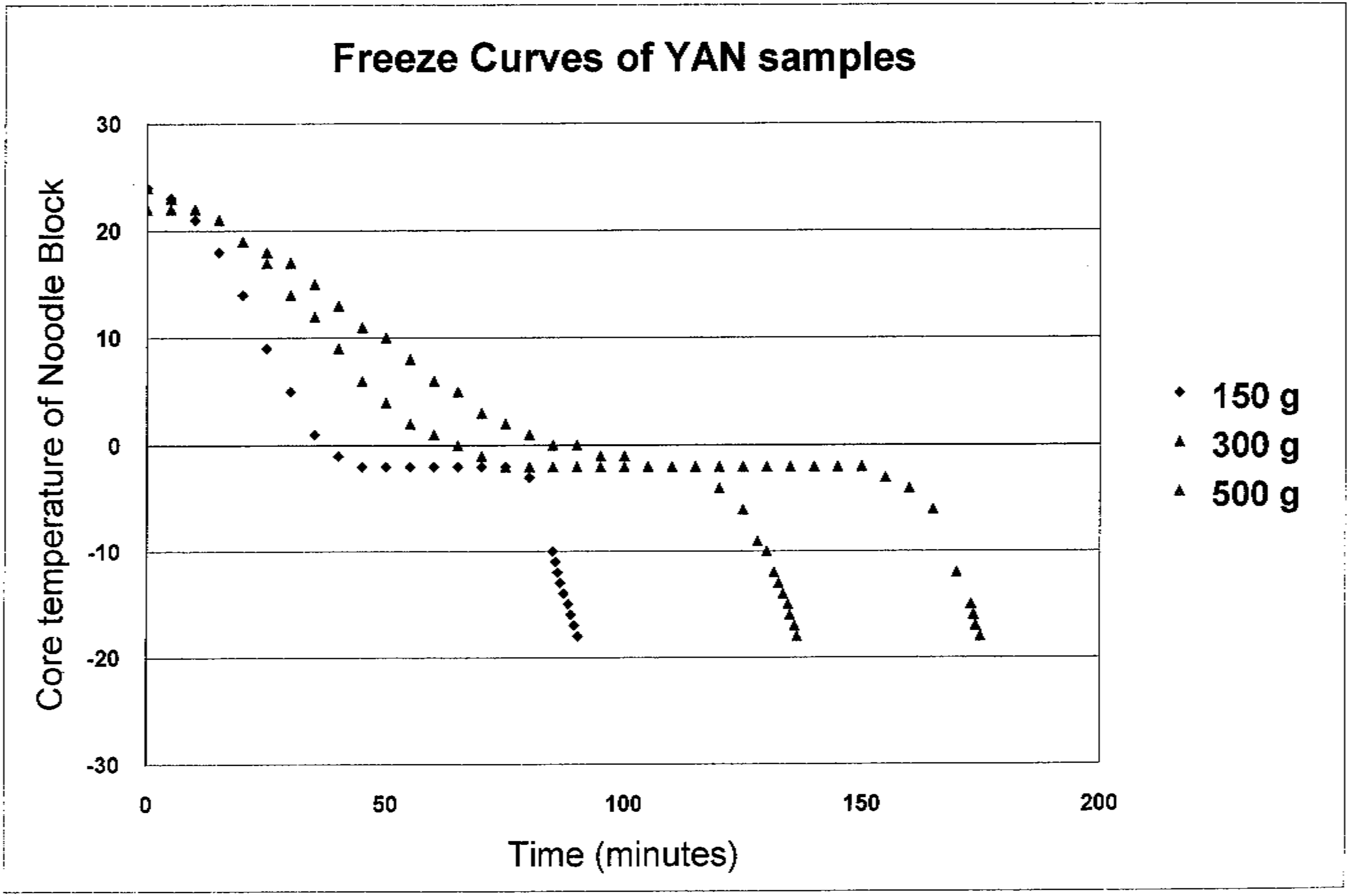
- The comparison between the freeze rates of similar samples in either a normal storage freezer (air temperature approximately -18°C) or shock freezing in the IRINOX was also made. To determine the core temperature in sample in a conventional freezer required a thermocouple that was suitable for temperatures around -20°C. The illustration below shows the setup that was used:



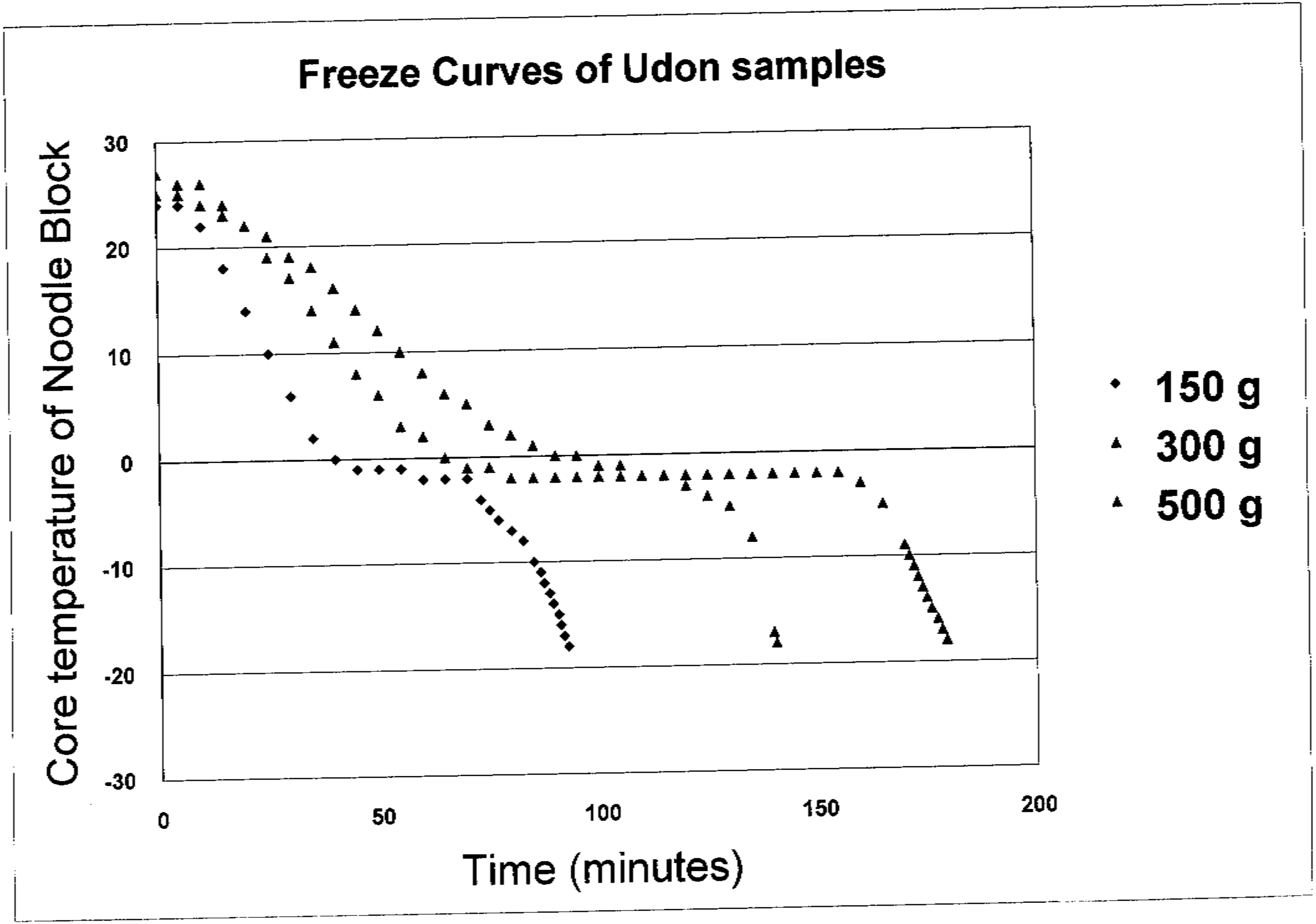
The further research planned in this project will involve characterisation of the products obtained by changing the noodle properties.

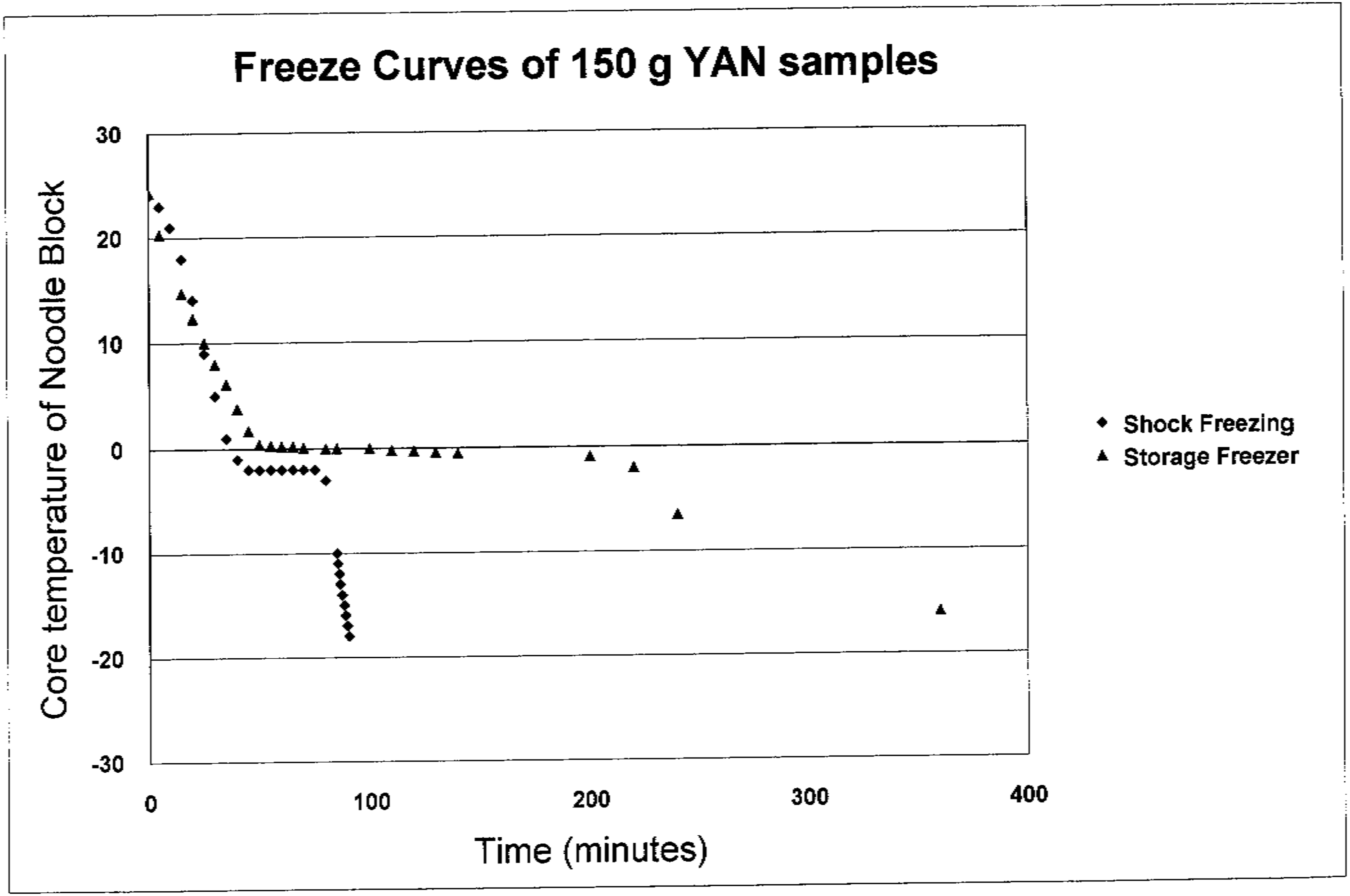
- The effects of different protein levels will be studied by comparing noodles made from APH (high), APW (medium) and ASW (low), and how they are effected by freezing.
- Similarly, the effects of varying starch paste viscosity is to be investigated by contrasting noodle made from Batavia, Exadu, Janz and Vectis flours.
- The influence of salt content will be done by looking at noodles of 0.0%, 0.5%, 1.0% and 2.0% salt.
- To look at the repercussions of varying water content, samples of 30%, 35% and 40%. The freezing in these cases will occur on the raw noodle sample.
- The effects of freeze / thaw cycling will be studied by comparing noodle samples that have undergone 0, 1, 2 and 3 cycles. The thawing process can be performed in the IRINOX, on the defrost cycle for 30 minutes, to ensure that it is reproducible.

Many thanks must be giving to both Agrifood Technology and the Quality Wheat CRC for providing training, resources and funding.

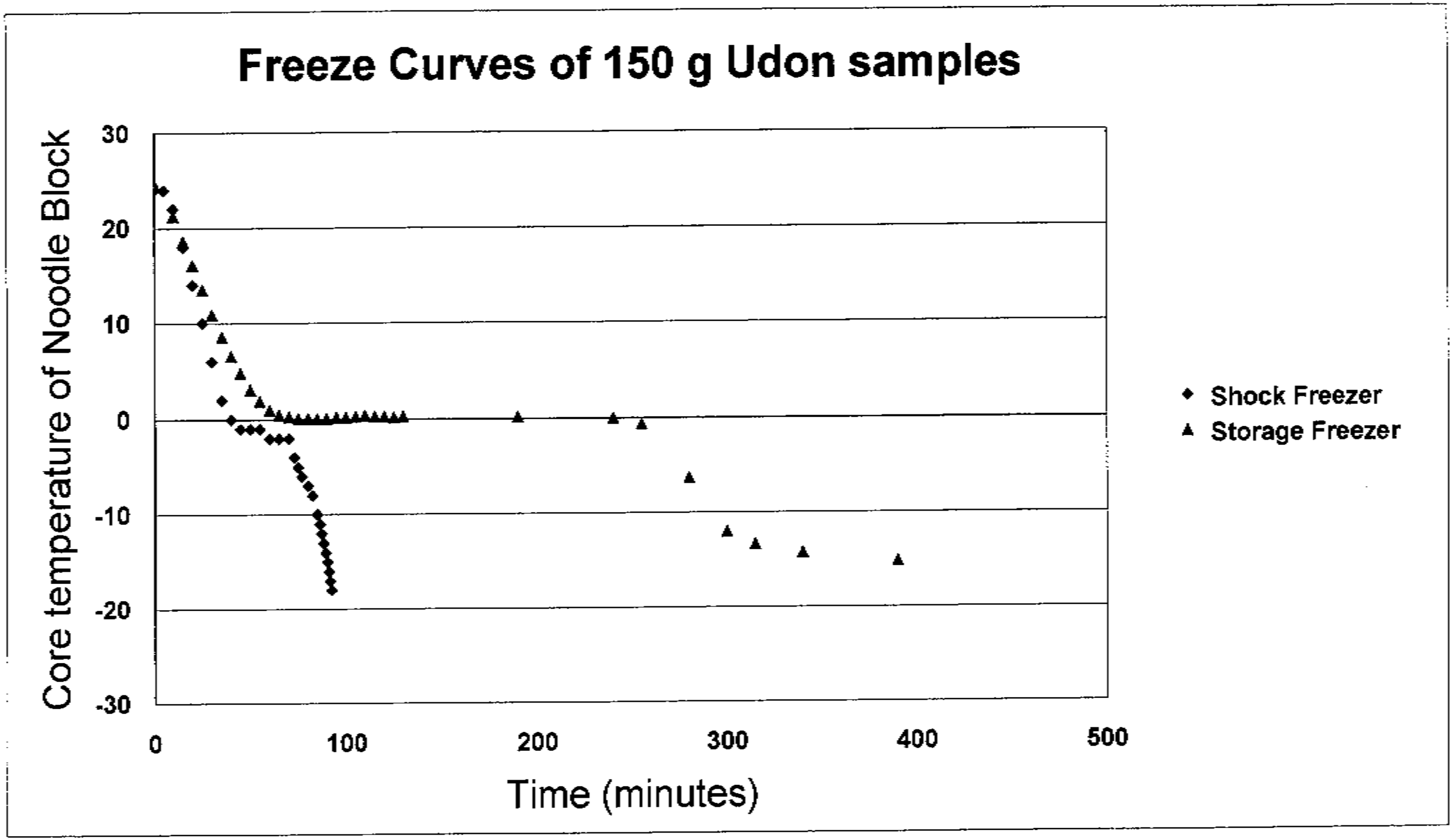


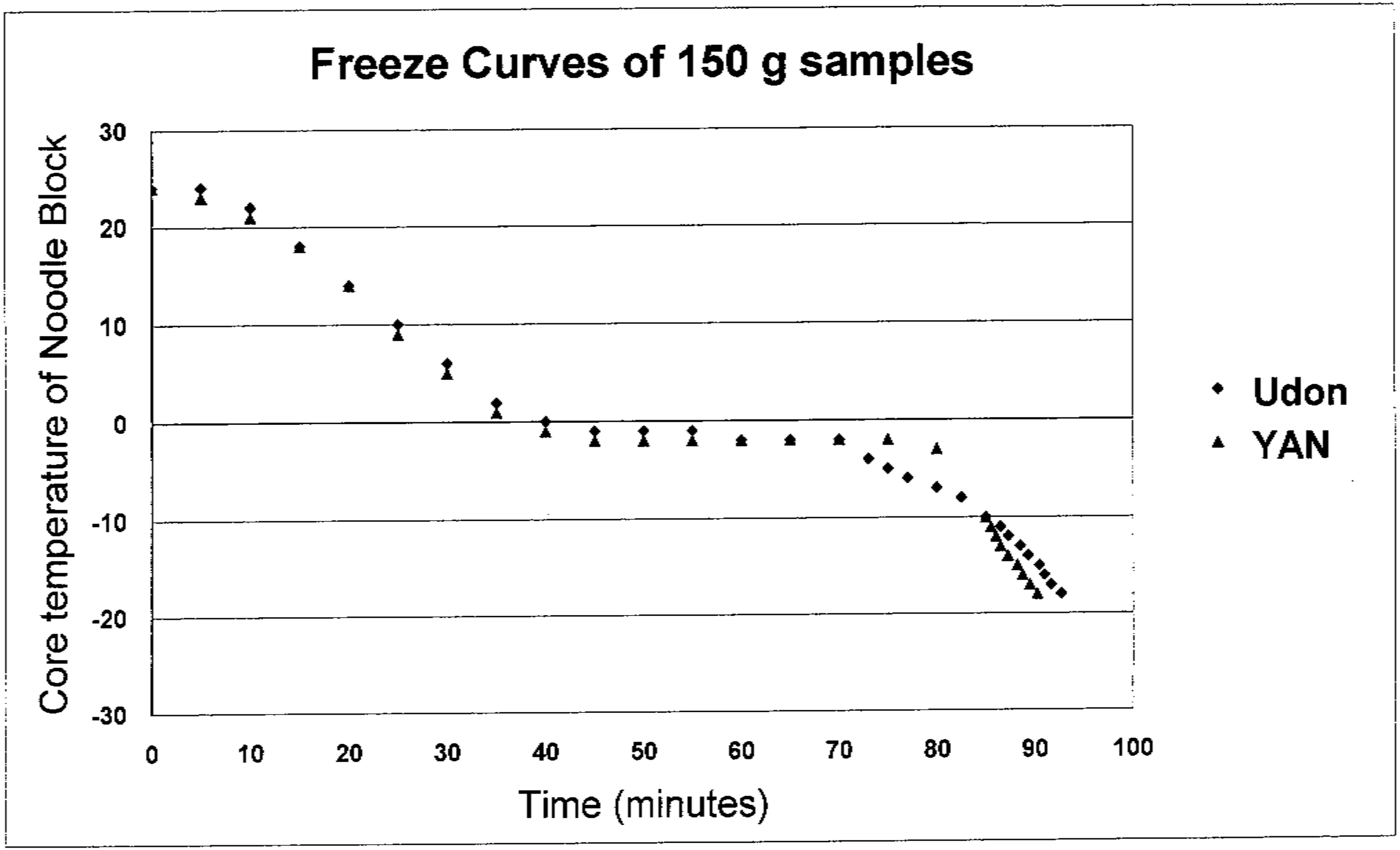
Freeze Curves of YAN samples
Core temperature of Noodle Block
30
20
10
0
-10
-20
-30
0
50
100
150
200
Time (minutes)
150 g
300 g
500 g

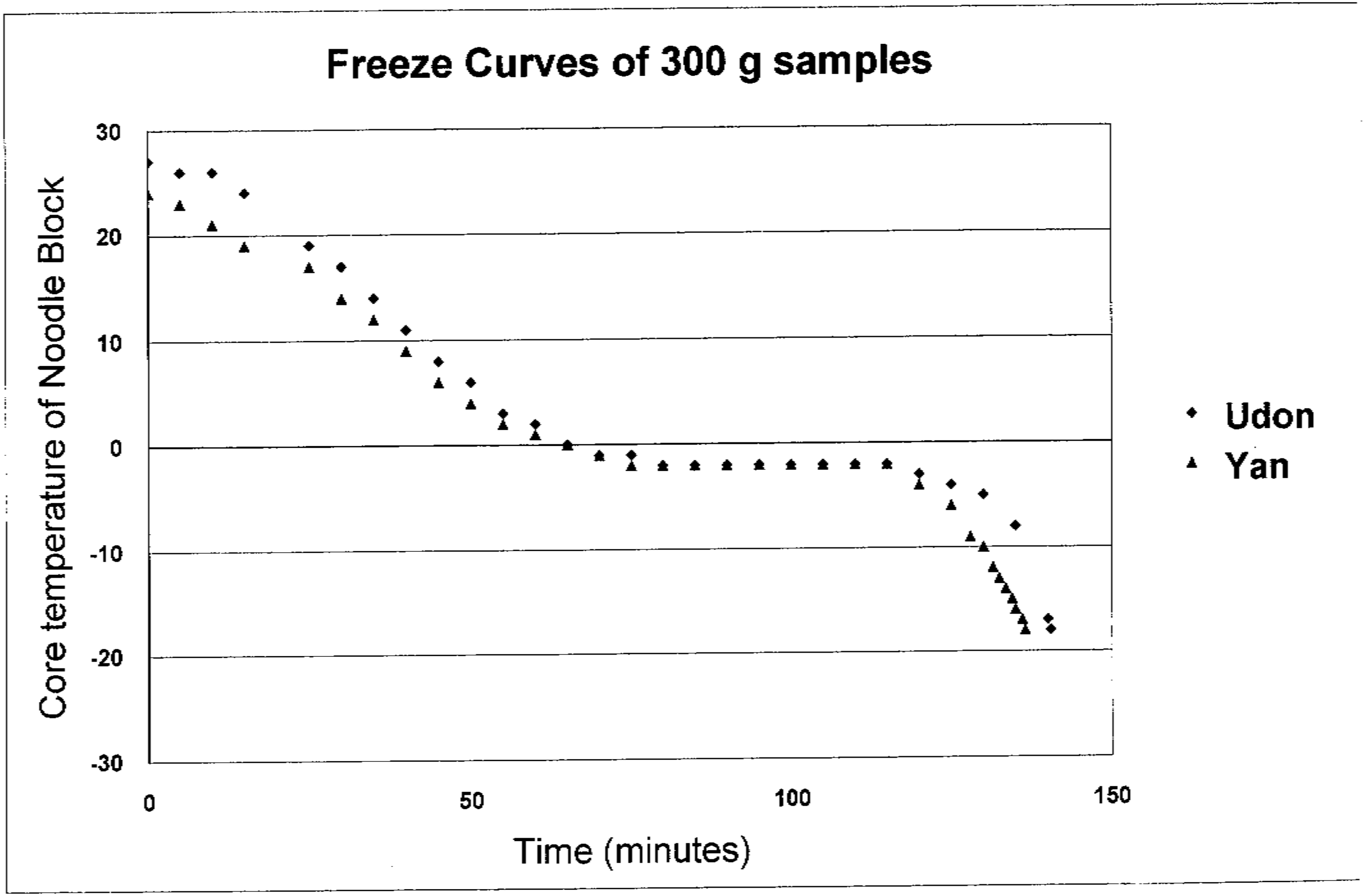

Freeze Curves of Udon samples
Core temperature of Noodle Block
30
20
10
0
-10
-20
-30
0
50
100
150
200
Time (minutes)
150 g
300 g
500 g

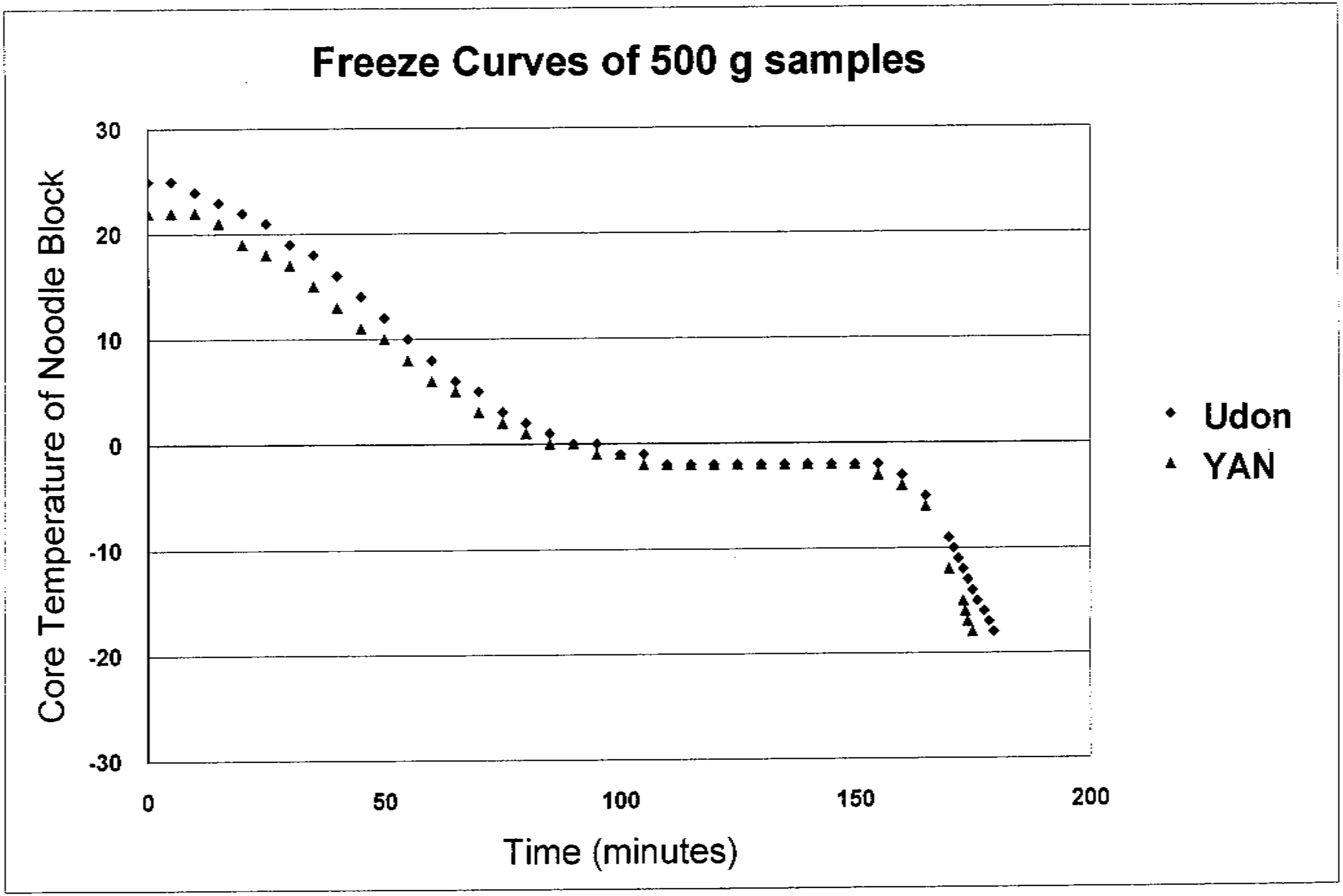


Freeze Curves of 150 g YAN samples
Core temperature of Noodle Block
30
20
10
0
-10
-20
-30
0
100
200
300
400
Time (minutes)
Shock Freezing
Storage Freezer


Freeze Curves of 150 g Udon samples
Core temperature of Noodle Block
30
20
10
0
-10
-20
-30
0
100
200
300
400
500
Time (minutes)
Shock Freezer
Storage Freezer

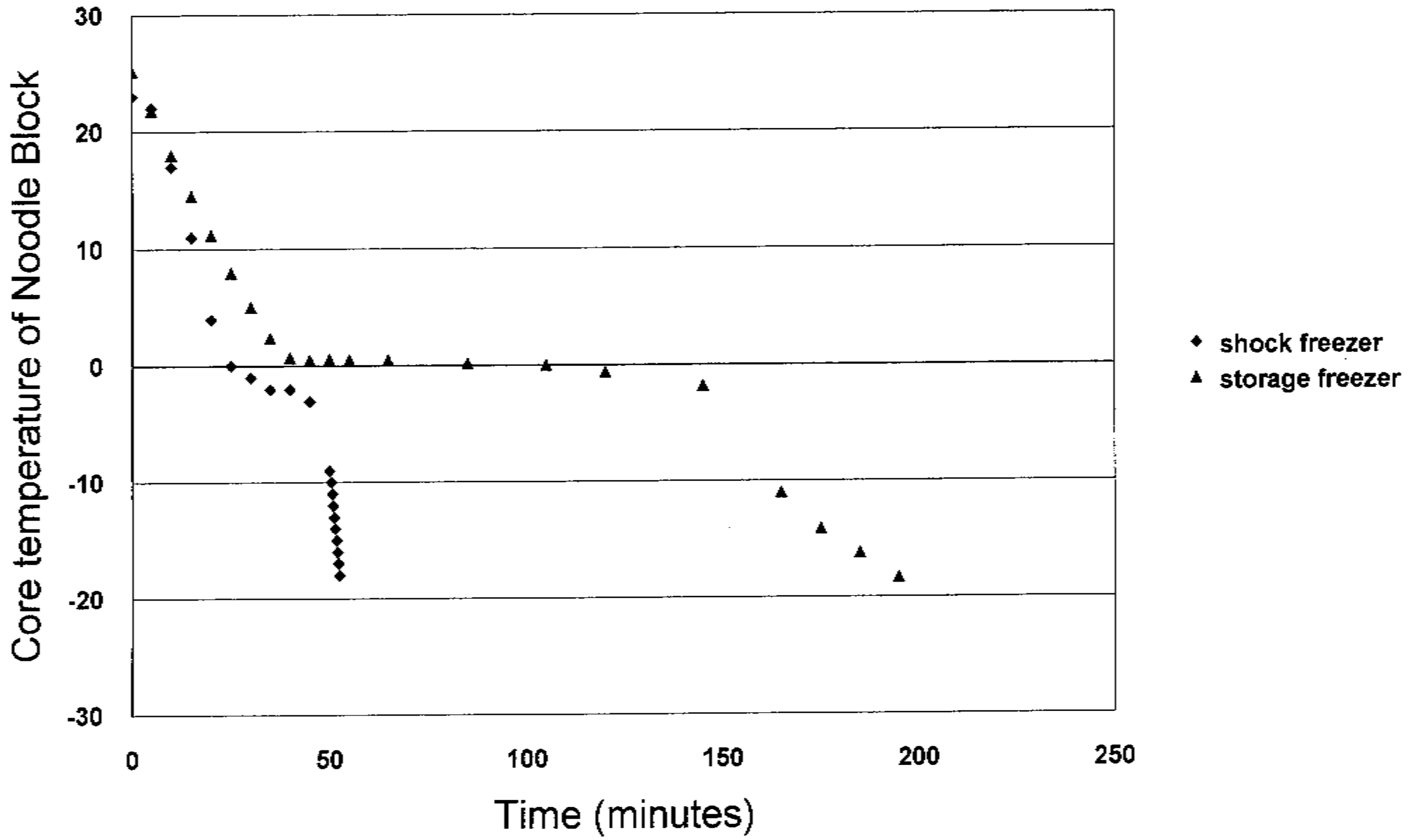

Freeze Curves of 150 g samples
Core temperature of Noodle Block
Time (minutes)
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100
Udon
YAN

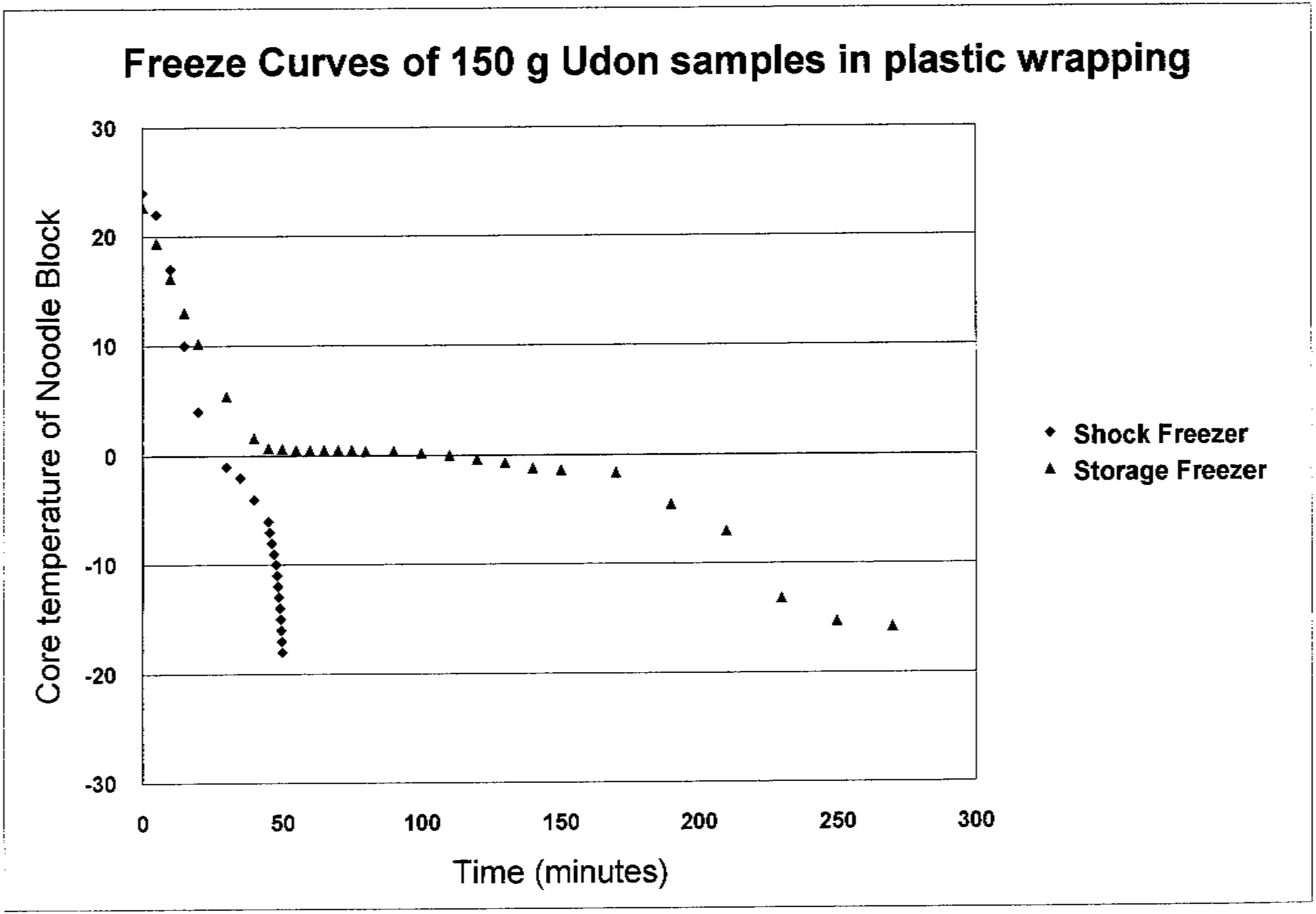

Freeze Curves of 300 g samples
Core temperature of Noodle Block
30
20
10
0
-10
-20
-30
0
50
100
150
Time (minutes)
Udon
Yan



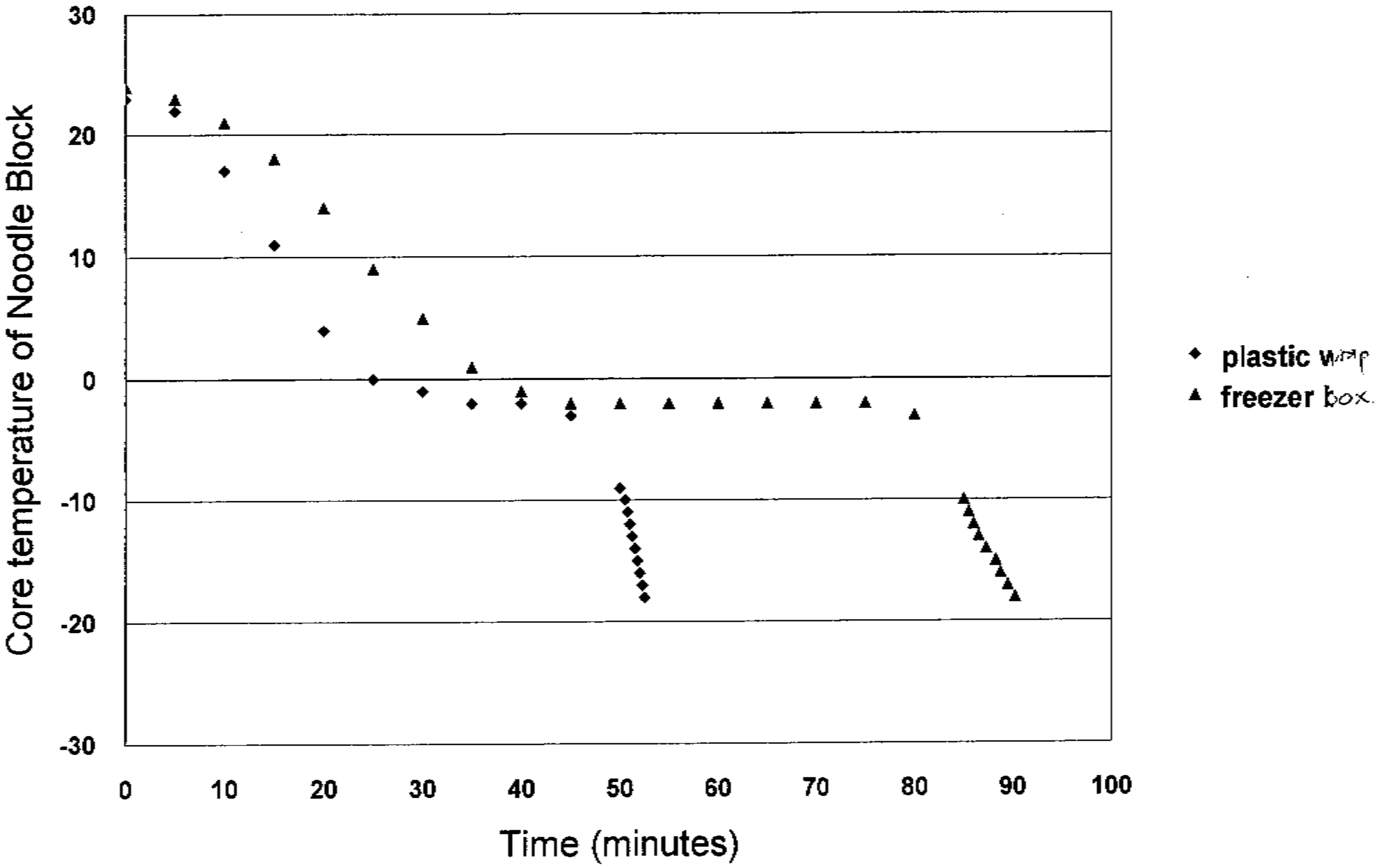
Freeze Curves of 500 g samples
Core Temperature of Noodle Block
30
20
10
0
-10
-20
-30
0
50
100
150
200
Time (minutes)
Udon
YAN

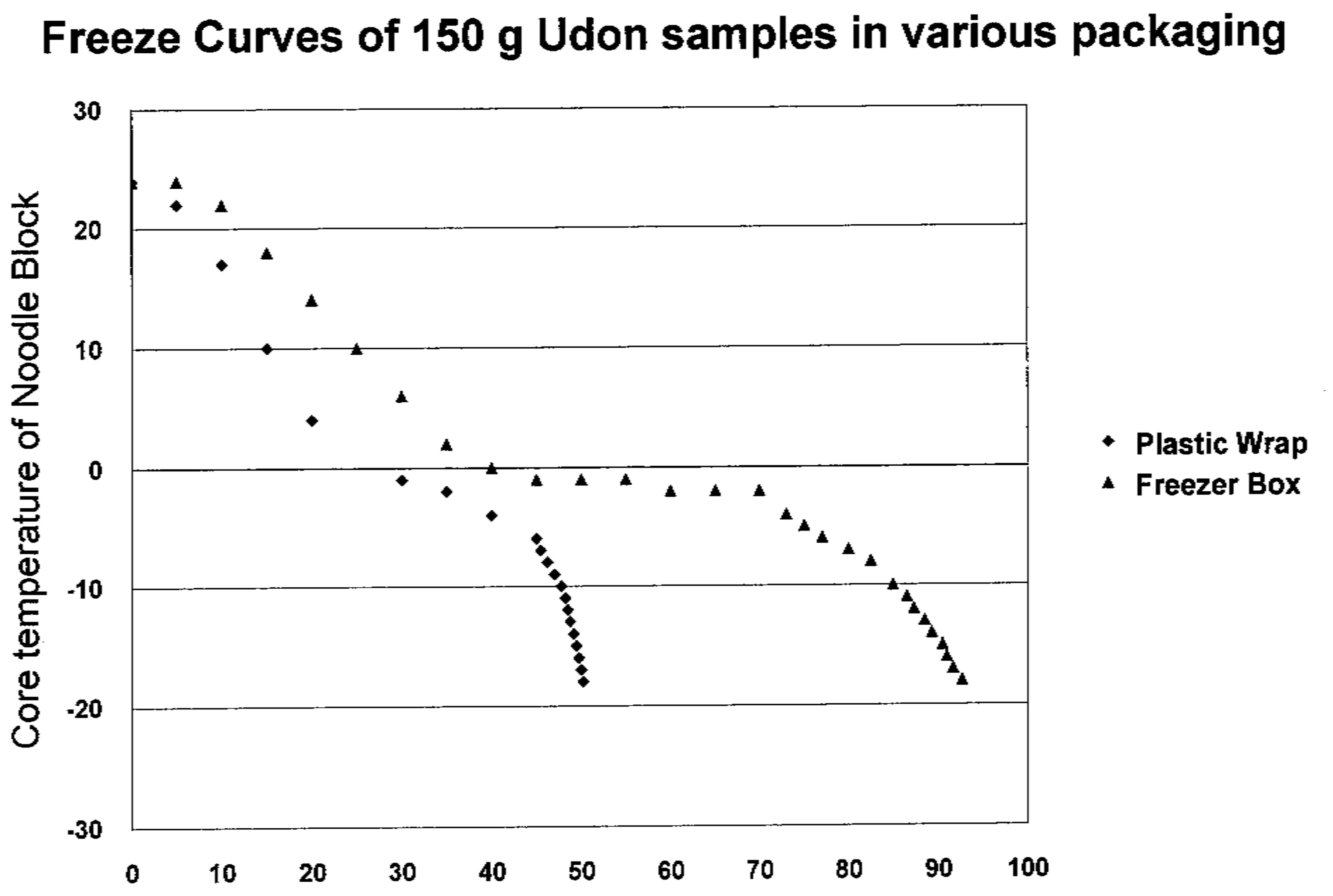
Freeze Curves on 150 g YAN samples in plastic wrapping




Freeze Curves of 150 g Udon samples in plastic wrapping
Core temperature of Noodle Block
30
20
10
0
-10
-20
-30
0
50
100
150
200
250
300
Time (minutes)
Shock Freezer
Storage Freezer

Freeze Curves of 150 g YAN samples in various packaging




Freeze Curves of 150 g Udon samples in various packaging
Core temperature of Noodle Block
30
20
10
0
-10
-20
-30
0
10
20
30
40
50
60
70
80
90
100
Plastic Wrap
Freezer Box

Wendy Leung

Investigation of Lubrication in Biaxial Extension Measurements

Supervisor: R. Tanner, Mechanical Engineering,
University of Sydney

Interim Report

BIAXIAL EXTENSION MEASUREMENTS OF PLAY-DOH

Wendy Leung
Supervisor: Professor Roger Tanner, Department of Mechanical Engineering, University of Sydney

Abstract

A lubricated squeeze film apparatus was used to perform biaxial extension measurements on play-doh. The aim was to see if the presence of a lubricant between the sample and platen walls affected the sample's final height. Four different weight sets were employed to squeeze the play-doh between two 3 cm-diameter platens. Two initial sample heights of 0.873 mm and 1.873 mm were used, and final heights were measured when the reading did not change after 10 minutes. The final height was found to be lower for the lubricated samples than the unlubricated ones. The difference between the lubricated and unlubricated measurements decreased as the weight increased due to a gradual loss of the lubricant film. A lower initial height resulted in a lower final height. The total height displacement was also lower.

Introduction

Biaxial extension is equivalent to stretching a thin sheet of material in two orthogonal directions simultaneously, with a corresponding decrease in sheet thickness. It is found (approximately) when a circular free jet impinges on a flat plate or in a lubricated squeeze film flow and when a balloon is inflated.[1] Gas cell expansion for loaf volume development during baking is also largely a biaxial stretching flow.[2,3]

In this study, biaxial extensional creep first developed by Chatraei *et al* [4] was performed on play-doh. It is basically the lubricated squeeze film flow method, compressing a viscous material between two discs whose surfaces are lubricated. The purpose of the lubricant between sample and wall is achievement of a vanishing shear stress.[4] Without lubrication we would have the well known squeezing of Stefan flow which is a combination of shear and extension.[5] The aim of this study was to investigate if lubrication affected the final height of the material. The final height is the height at which no further compression of the material occurs.

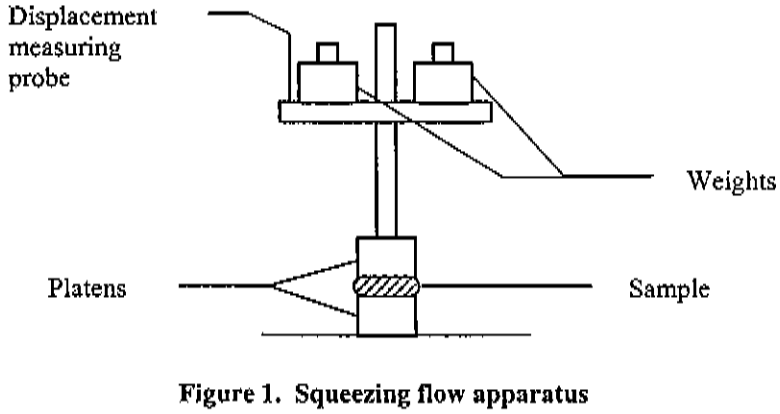


Figure 1. Squeezing flow apparatus

The experimental apparatus is shown in Figure 1. The platens each had a diameter of 30 mm. Four different weight sets were employed: No weights, Small weights, Large weights, and Both small and large weights. The LVDT core had a mass of 1 kg, the two small weights had masses of 0.5089 kg and 0.5090kg, and the large weights had masses of 1.0085 kg and 1.0104 kg. This corresponds to four different stress levels: 13.9kPa, 28.0 kPa, 41.9 kPa and 56.0 kPa.

First, the measurements were taken with no lubricant. Two initial sample heights were set at 0.873 mm and 1.873 mm. The final height was calculated by using a displacement measurer (MERCER 122), and was taken when the reading did not change after 10 minutes. The measurement readings were repeated using a lubricant, by coating both surfaces of upper and lower platens with a thin layer of sunflower oil ($\eta = 6.2 \times 10^{-2}$ Pa.s). All measurements were carried out at 21°C.

Results

Figures 2 and 3 show that for both initial heights, the lubricated platens squeeze the material more than the unlubricated ones, resulting in a lower final height. Therefore, for a particular force, not only does lubrication cause the platens to squeeze more rapidly[4], it also causes them to squeeze to a greater extent. The trend of decreasing final height with stress is expected, because a greater force (more weights) will ultimately cause greater deformation to the material. The difference in final heights between the lubricated and unlubricated samples is shown to decrease for increasing stress. This is probably due to a gradual loss in lubricant, as more of it is squeezed out of its space between sample and wall under higher forces. To achieve more reliable lubrication, a lubricant with a higher viscosity than the one used in this experiment may be preferred.

Figure 2. Final heights for samples with 0.873mm initial height

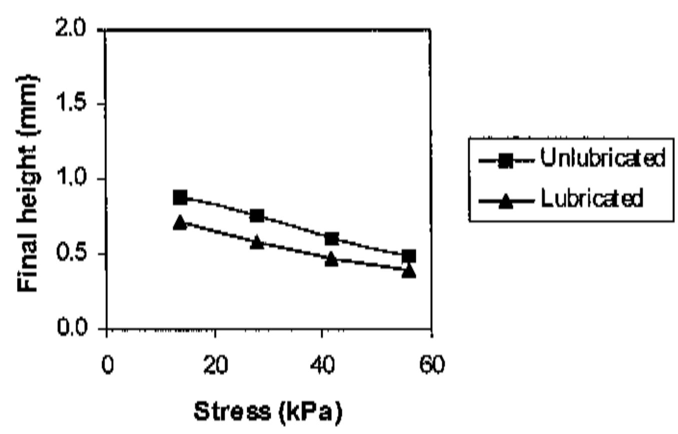
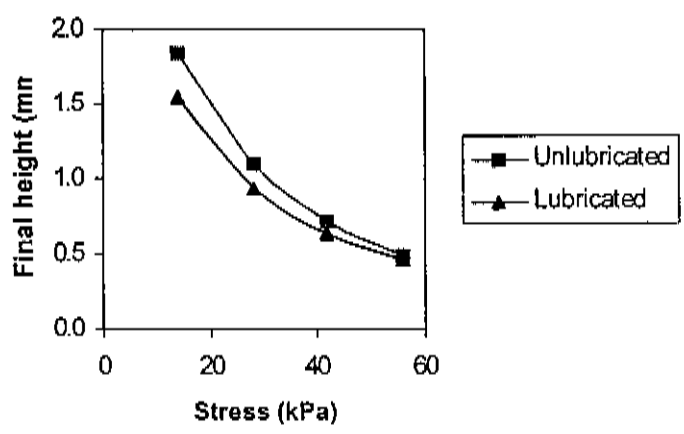


Figure 3. Final heights for samples with 1.873mm initial height



For both lubricated and unlubricated cases, a lower initial height results in a lower final height. This is shown in Figures 4 and 5. However, as the force increases this difference due to initial heights diminishes, and for the unlubricated case at 56 kPa stress there is no difference at all as two samples are both squeezed to the same thickness.

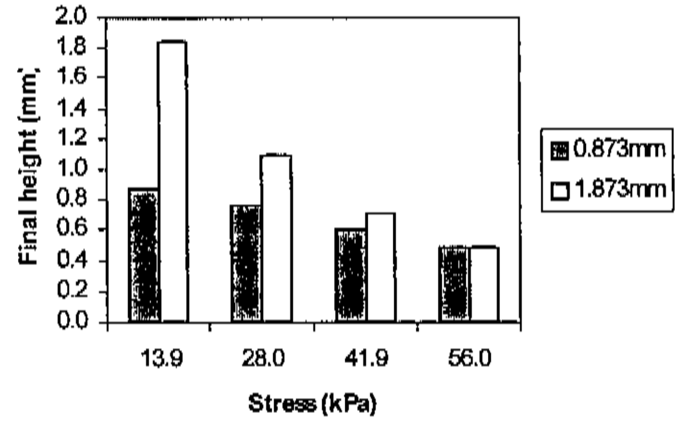


Figure 4. Final heights for unlubricated samples

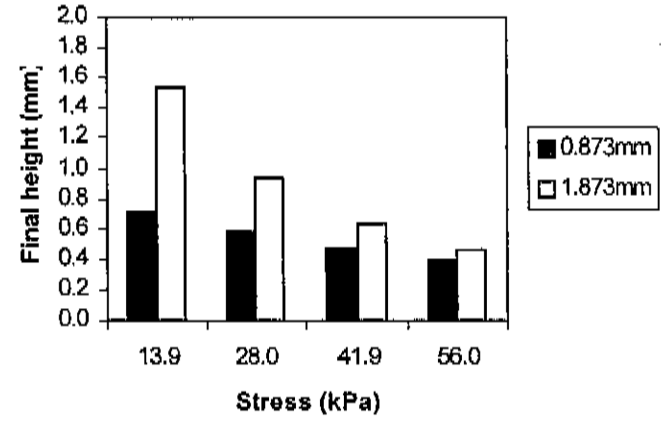


Figure 5. Final heights for lubricated samples

Figures 6 and 7 reveal that under the same force, more material displacement occurs if the initial height is higher. So although a sample with a higher initial height is compressed to a higher final height, the actual height displacement is also higher.

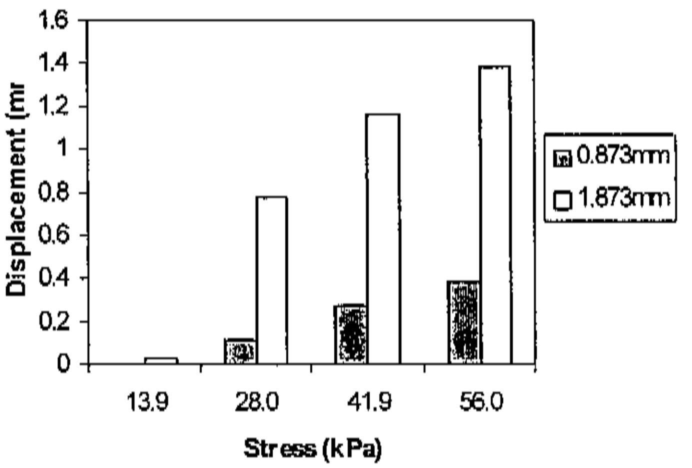


Figure 6. Height displacements for unlubricated samples

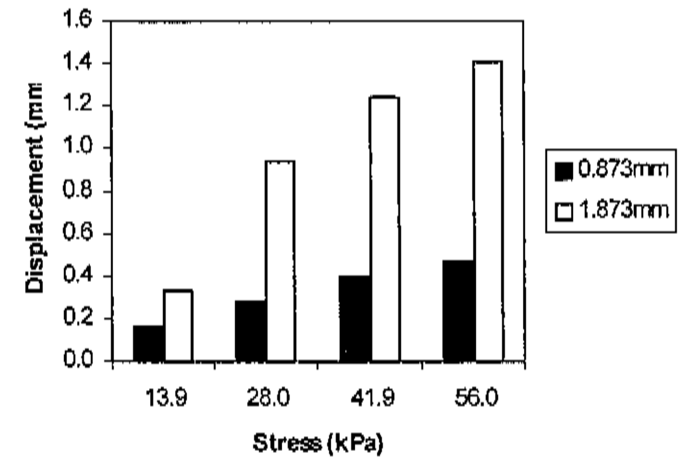


Figure 7. Height displacements for lubricated samples

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[3] D.W. de Bruijne, J. de Looff, and A. van Eulem, The rheological properties of bread dough and their relation to baking, *Rheology of Food, Pharmaceutical and Biological Materials with General Rheology*, edited by R.E. Carter, Elsevier, New York, pp. 269-283 (1990).

[4] S. H. Chatraei, C.W. Macosko, and H.H. Winter, Lubricated squeezing flow: a new biaxial extensional rheometer, *J. Rheol.* 25, 433-443 (1981).

[5] P.J. Leider, *Ind. Eng. Chem. Fundam.*, 13, 342 (1974) and R.B. Bird, R.C. Armstrong and H.O. Hassager, *Dynamics of Polymeric Liquids*, Wiley, New York, 1977, Vol. 1, Chap. 1.

Wendy Leung

Investigation of Biaxial Stretching of Bread Dough: Computer Simulation of Squeeze Film Flow

Supervisor: R. Tanner, Mechanical Engineering,
University of Sydney

Final Report

COMPUTER SIMULATION OF SQUEEZE FILM FLOW

Wendy Leung
Supervisor: Professor Roger Tanner, Department of Mechanical Engineering, University of Sydney

Abstract

An existing computer program called AXFINR was used to solve the squeeze film problem for a Newtonian material. The program is a finite element scheme suitable for incompressible fluid flow in plane and axisymmetric geometries, constructed by using a Galerkin method.[1] Both lubricated and unlubricated squeeze film problems were simulated using a 12-by-11 mesh. The velocity and pressure distributions differ markedly for the two cases. Numerical data on the pressure and weight agree well with analytical solutions, except near the edge for the unlubricated case due to the singular corner points. A finer 17-by-11 mesh was used to improve the results, but inaccuracies still existed because of the singular points.

Introduction

Squeeze film flow is the compression of a viscous fluid between two parallel plates. In this study, the aim is to use numerical methods to represent the squeeze film flow of a Newtonian fluid for both lubricated and unlubricated plates. A finite element computer program called AXFINR was used to solve the problem. This program is a system of FORTRAN routines that can be used to solve, approximately, axisymmetric or plane fluid mechanics problems having a free-surface boundary condition, with a non-Newtonian constitutive equation.[1]

Figure 1 shows the squeeze film geometry and the symbols used to represent measurements. The two parallel plates are circular, radius *R*, but a two-dimensional version of this problem with axes *r* and *z* was used. The fluid with height *h(t)* is compressed between the plates and its resistance generates the squeeze-film load *W*. The origin of co-ordinates was taken at the centre of the discs so that the problem is symmetrical, and the top plate approaches the origin at a speed $\dot{h}$ while supporting a load *W*, with the bottom plate stationary.

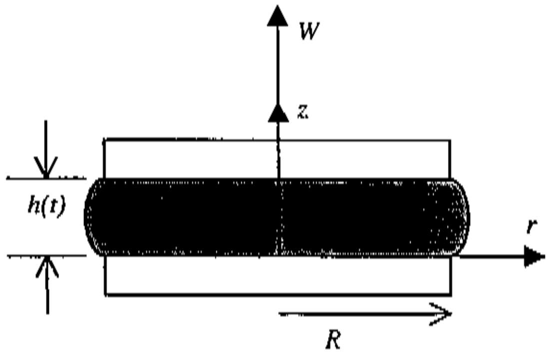

Figure 1. Squeeze film geometry. Shaded area is fluid.

Boundary conditions were imputed into the program using a 12-by-11 mesh covering the fluid from the centre of the disc to the edge. The problem was solved for a

Newtonian fluid with viscosity 1, height 0.3, radius 2, and the top plate moving with velocity of −1. Results were obtained for both lubricated and unlubricated plates. A finer 17-by-11 mesh was used to run the program again for unlubricated plates.

Analytical solutions for lubricated squeeze film flow is obtained by firstly assuming a homogeneous deformation with perfect slip of the sample at the wall.[2] The Hencky strain in the vertical direction is then:

$$\epsilon = \ln\left(\frac{h}{h_0}\right)$$

the strain rate is:

$$\dot{\epsilon} = \frac{d\epsilon}{dt} = \frac{\dot{h}}{h}$$

and the stress is :

$$p = \eta\,\dot{\epsilon}$$

For unlubricated squeeze film flow, the stress for the Newtonian solution is obtained by:[3]

$$p = \frac{3\eta}{h^3} \cdot \frac{dh}{dt}\left\{r^2 - R^2\right\}$$

and hence the force W required to maintain the plate motion is:

$$W = -\int_0^R 2\pi r p \cdot dr = \frac{3\pi}{2}\eta R^4 \frac{\dot{h}}{h^3}$$

Results

Figure 2 shows the mesh set up by AXFINR and the nodal points at which problem variables were calculated. Finite element methods cover the fluid-filled region with an irregular mesh, usually made up from quadrilaterals or triangles.[3] In this case, curvilinear quadrilaterals were used so that a close fit to irregular boundary shapes may be arranged.

The velocity vector for lubricated squeeze flow of a Newtonian fluid is shown in Figure 3. The results show that the fluid is squeezed out to the sides as the top plate moves down, with the fluid near the edge flowing the fastest. Figures 4 and 5 reveal that the velocity increases linearly in both axial directions. Velocity u in the radial (r) direction increases uniformly from 0 at the plate centre to about 3.3 at the edge, and velocity w in the axial (z) direction increases uniformly from 0 at the bottom plate to −1 at the top plate.

The analytical solution for stress on a fluid undergoing lubricated squeeze flow was calculated to be a uniform value of 3.33. This agrees with the finite element solution as shown in Figure 6, and errors of no more than 0.3% were obtained by the method.

Figure 7 shows the velocity vector for unlubricated squeeze flow of a Newtonian fluid. The fluid near the edge flows the fastest, but shear stress at the top plate prevents allows movement in the axial direction only. The velocity contours are markedly different from those for the lubricated case, as Figures 8 and 9 show. Velocity *u* increases from the centre to the edge in a parabolic pattern, agreeing with theory. Velocity *w* decreases from the top plate to the bottom, is nonlinear, and is independent of *r* for most points except near the edge. This is consistent with theory except where the singularity at the two edge corners create problems in the method.

The singularity also causes error in the pressure solutions, as revealed by Figures 10 and 11. The pressure values agree with analytical solutions with an error of 0-2%, but near the edge the error becomes as high as 18%. The weight on the top plate was calculated by Simpson's Rule after replacing the incorrect edge pressures with the correct value of zero; it was calculated to be –2837 and agrees well analytically with 2% error.

An advantage of the finite element system is that it permits a closer 'mesh' near the singular points. However, no finite mesh can exactly capture the singular behaviour there.[3] This is shown in Figures 12 to 15. A finer mesh near the edge was used to run the program, and although better results were obtained, inaccuracies still exist near the edge, as Figures 14 and 15 indicate.

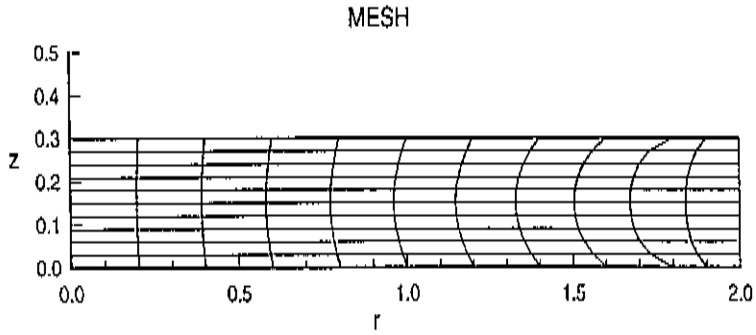

Figure 2. 12-by-11 mesh set up by AXFINR

References

[1] R.I. Tanner, R.E. Nickell and R.W. Bilger, *Finite Element Methods for the Solution of Some Incompressible Non-Newtonian Fluid Mechanics Problems with Free Surfaces*, Computer Methods in Applied Mechanics and Engineering 6 (1975) 155-174.

[2] S.H. Chatraei , C.W. Macosko and H.H. Winter, *Lubricated Squeezing Flow: a New Biaxial Extensional Rheometer*, J. Rheol. 25 (1981) 433-443.

[3] R.I. Tanner, *Engineering Rheology*, Oxford University Press, Oxford, 1985, pp. 259-261, pp. 312-316.

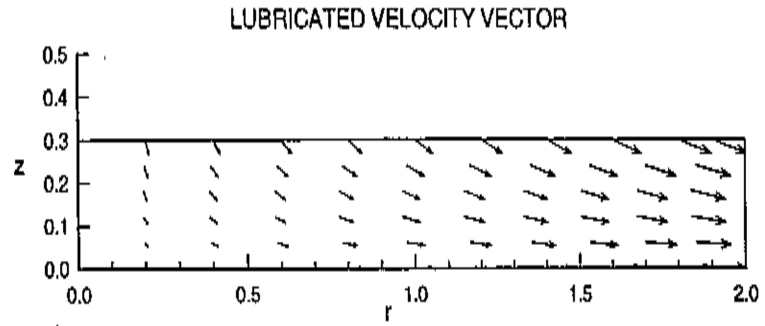

Figure 3. Velocity vector for lubricated squeeze flow using 12-by-11 mesh

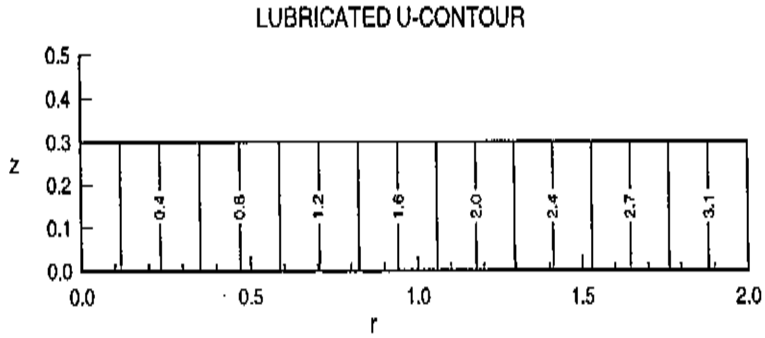

Figure 4. Contour plot of velocity in the radial direction for lubricated squeeze flow using 12-by-11 mesh

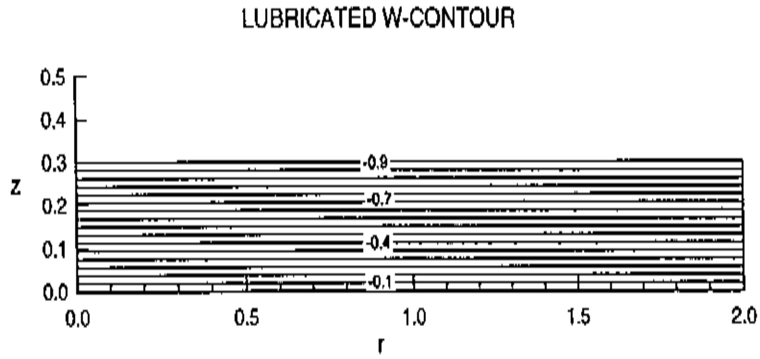

Figure 5. Contour plot of velocity in the axial direction for lubricated squeeze flow using 12-by-11 mesh

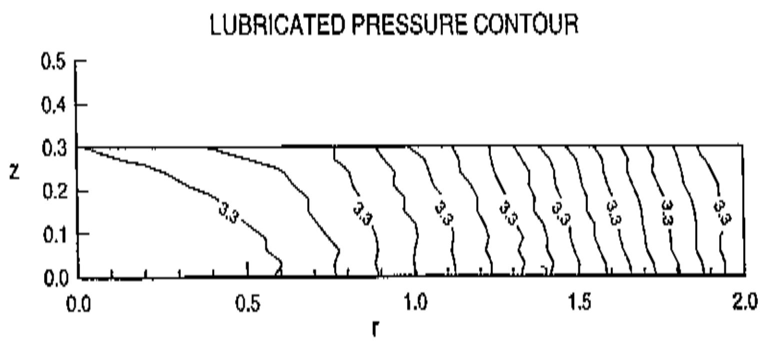

Figure 6. Pressure contours for lubricated squeeze flow using 12-by-11 mesh

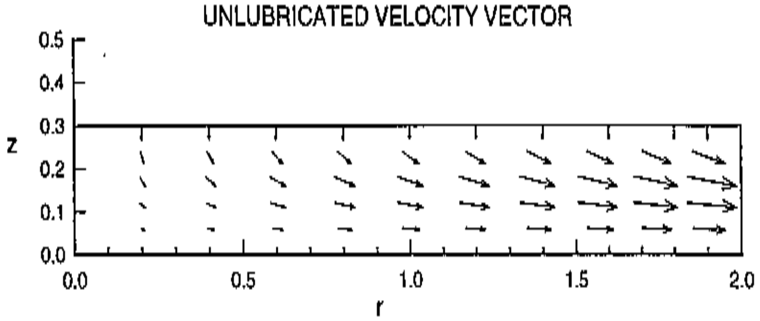

Figure 7. Velocity vector for unlubricated squeeze flow using 12-by-11 mesh

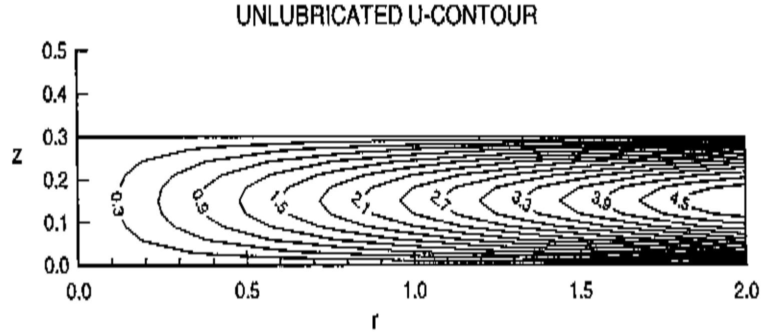

Figure 8. Contour plot of velocity in the radial direction for unlubricated squeeze flow using 12-by-11 mesh

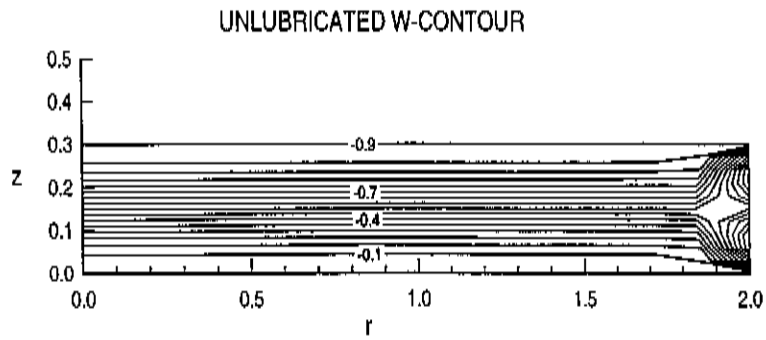

Figure 9. Contour plot of velocity in the axial direction for unlubricated squeeze flow using 12-by-11 mesh

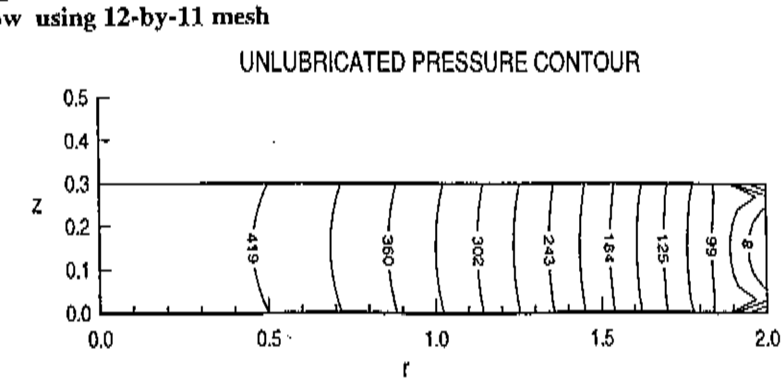

Figure 10. Pressure contours for unlubricated squeeze flow using 12-by-11 mesh

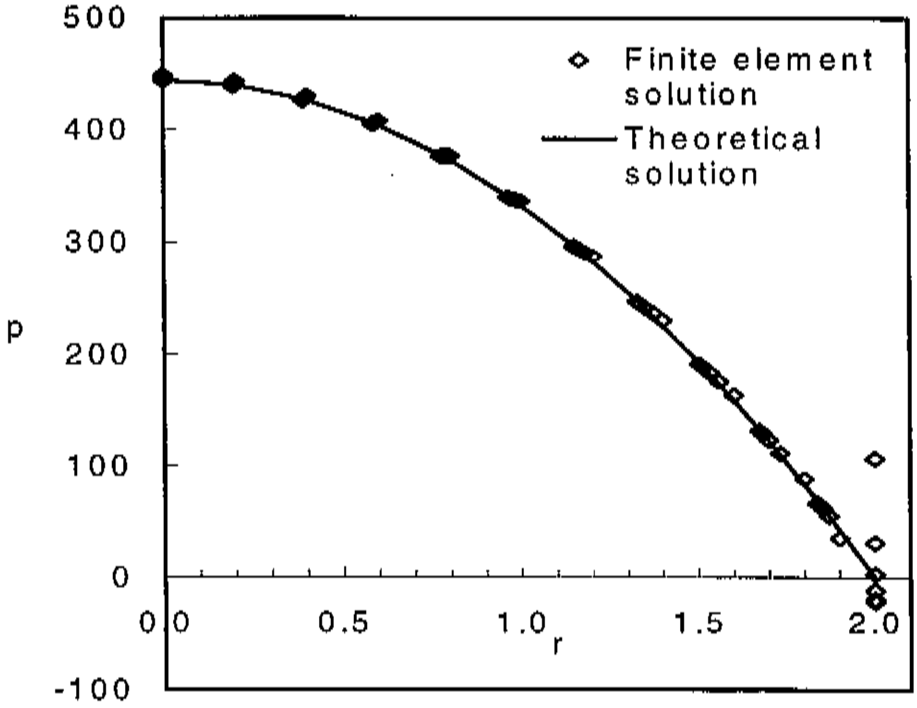

Figure 11. Comparison of finite element method and analytical solutions for pressure in unlubricated squeeze flow using 12-by-11 mesh

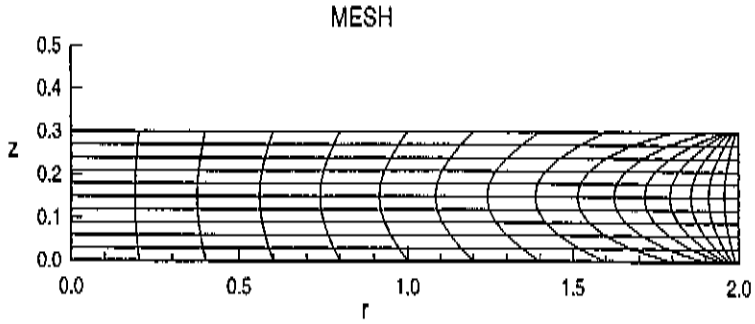

Figure 12. 17-by-11 mesh set up by AXFINR

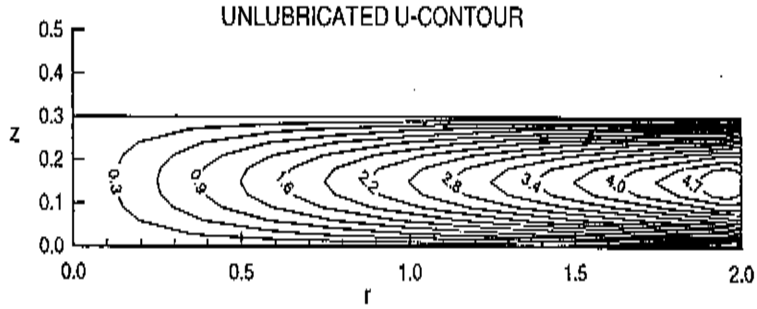

Figure 13. Contour plot of velocity in the radial direction for unlubricated squeeze flow using 17-by-11 mesh

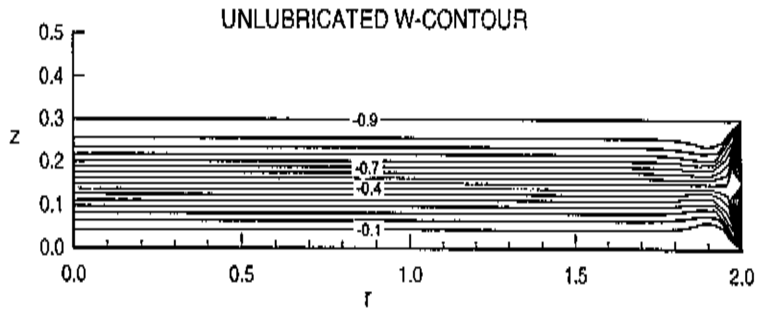

Figure 14. Contour plot of velocity in the axial direction for unlubricated squeeze flow using 17-by-11 mesh

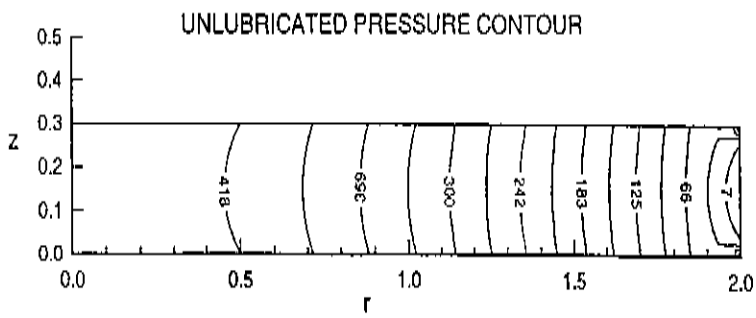

Figure 15. Pressure contours for unlubricated squeeze flow using 17-by-11 mesh

Keith Leong

(a) Dough Rheology of Heat Treated Flours
(b) High Speed Dough Tester Trial

Supervisor: E. Hocking, Weston Food Laboratories, Enfield

Final Report

Dough Rheology of Heat Treated Flours

Wheat flour is used in the manufacture of a variety of products such as breads, cakes, biscuits, cereal-based mixes, frozen or refrigerated doughs and batters, cream sauces, soups, candies, etc. This emphasizes the need for audit in the area of microbiological concerns.

Tempering of grains for flour manufacture may be carried out in chlorinated water if particularly low levels of microorganisms are desired. Bleaching with benzoyl peroxide is another options, but this reduces microbial numbers to some degree with the spores being little affected.

Objective

The objective of this project is to determine whether heat treatment offers an alternative for the sterilization of flours. To investigate the effects of heating flours to different temperatures on microbial counts and on dough rheological properties.

Two types of flours (soft and hard) were heat treated using a *Rotoniser*. The Rotoniser consist of three zones of heating infra red lamps running in series. Within each zone, there are two lamps. These lamps are positioned inside the rotating tunnel, where the tunnel is set at a fixed angle. The flours are fed into the tunnel by a vibrating hopper system. The feed rate of the flour samples can be adjusted according to the ambient conditions. The feed rate required for good final baking quality is around about 24 to 28 kg/hr.

In using the Farinograph and Extensograph to study heat treated flours, it was found that the tested samples needed to be moisture corrected first. This step is necessary as to account for the reduction of moisture within the flours during the heating process.

Three basic methods can be used in running a flour-water curve with the Farinograph:

- Constant dough-weight method
- Constant flour-weight method
- Flour as-is moisture-basis method

When the *constant flour-weight* method is used, the amount of flour used must be corrected to give 50 or 300g of flour on a 14% moisture basis. The *flour as-is* method uses 50 or 300g of flour without correcting for moisture content. The *constant dough-weight* method uses the correct amount of flour and water to give a dough weight of 80 or 480g (D'Appolonia, 1960).

The technique of constant flour-weight method was used, as this measures flour on a 14% moisture basis. This allows the same amount of dry matter to be tested in each case. Here, the same quantity of dough is not tested, because the quantity of dough varies with the absorption of the flour being tested.

Table 1 below shows a comparison between the constant flour-weight method and the as-is moisture-basis method for a soft and hard flour heat treated to 120°C. This table highlights the need for moisture correction when testing heat treated flours. The constant flour-weight method accounts for the dehydration process that has occurred, whereas the as-is moisture-basis does not. This is why the water absorption for the as-is moisture-basis are so much higher.

	Const Flour-Weight Method	As-is Moist-Basis Method	% Deviation
Flour Type:	Soft	Soft	-
Heat Treated Temp (°C):	120	120	-
Moisture %:	2.7	2.7	-
Mass of Sample (g):	265.2	300.0	13.1
Farinograph:			
Water Absorption %	53.6	74.6	39.2
Development Time (min)	16.0	22.5	40.6
Arrival Time (min)	1.4	2.5	78.6
Stability Time (min)	63.5	63.5	0
Break Down Time (min)	9	19	111.1
Flour Type:	Hard	Hard	-
Heat Treated Temp (°C):	120	120	-
Moisture %:	1.2	1.2	-
Mass of Sample (g):	261.1	300.0	14.9
Farinograph:			
Water Absorption %	63.8	90.7	42.2
Development Time (min)	7.9	10.0	26.6
Arrival Time (min)	2.2	3.6	63.6
Stability Time (min)	40.3	34.6	14.1
Break Down Time (min)	11	15	36.4

***Table 1:* Comparison between the Constant Flour-Weight method and the As-is Moisture-Basis method.**

The temperature range of heat treatments is from 80°C to 140°C. The Farinograph, Extensograph, Rapid Viscoanalyser and Starch Damage test have already been done. We are still at a stage of analyzing these results. Our next step is to rehydrate some of these samples and see what effects this would have.

Samples were collected straight from the Rotoniser into sterile jars at each temperature for microbiology analysis. The plate counts for hard flour is shown in *Figure 1*. The plate counts seem to decreases with temperature as one would expect. At 130°C and 140°C, the plate count was estimated to be 10 per gram. There were many scatters in the plate count for soft flour which is not shown here. The highest plate counted value for the soft flour was 2 000 per gram at 90°C. This is well under the median value counted of 4 000 per gram by Eyles *et al.*, (1989) over 24 samples of flour from Australian flour mills.

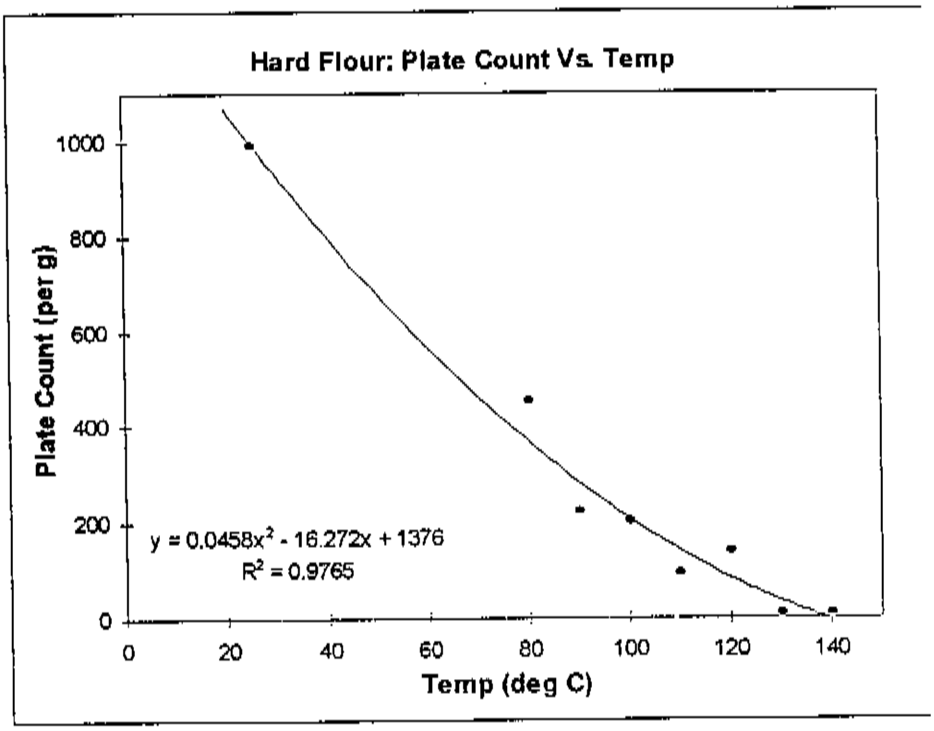

Figure 1: Plate count Vs. heat treated temperatures.

Reference

D'Appononia, B.L, and Kunerth, W.H., (1960) *The Farinograph Handbook*, 3rd ed, Americal Association of Cereal Chemists, Minnesota, USA.

Eyles, M.J., Moss, R. and Hocking, A.A. (1989) The microbiological status of Australian flour and the effects of milling procedures on the microflora of wheat and flour, *Food Australia*, 41, 704-8.

High Speed Dough Tester Trial

This part of the project is to evaluate the new High Speed Dough Tester (HSDT) machine as supplied by Feather Engineering. This machine offers an alternative to the traditional Brabender Farinograph for testing flour mixing properties. The new HSDT offer advantages over the traditional Brabender system in that its mixing speed can be varied from 20 to 190 RPM with the addition of set speeds at 63 and 180 RPM. The traditional Brabender system has only a fixed preset speed of 63 RPM. This variable speed alternative is very important, as it gives us the option of testing samples with condition consistent with industrial mixing speeds.

In the traditional Brabender Farinograph, the resistance the dough offers to the mixing blades during mixing is transmitted to a dynamometer, which is connected to a lever and scale system. The pen attached to the system traces a curve on a kymograph chart. In the new HSDT, the energy is transmitted as torque from a static dynamometer. This has negligible movement and mechanical lever and pendulum errors are eliminated. The curve is plotted onto the computer connected to the HSDT which can be saved and printed.

The Brabender Farinograph have fourteen friction points through its normal operation as counted by Feather Engineering. This instrument records a band with a certain width due to these friction points. This width is restricted by the inertia of the system and by the adjustable oil damper. The new HSDT claims to have eliminated some of these friction points, in that it gives a higher resolution and greater accuracy than current systems. These claims are yet to be tested, as it was only recently that the new software was up and running.

The new HSDT can be run via the DOS Brabender software or via Window through the use of a Genie software. The DOS Brabender system has been on the market for about 10 years. However, this system is very limited in that it only records Torque over time. The new Genie software which is still under development by Feather Engineering records Torque, Watts, RPM and Temperature over time.

The DOS Brabender software cannot be used at this stage, as the potentiometer supplied with the equipment does not have the range to calibrate it for used at 63 RPM.

Figure 1 shows a Farinograph for soft flour with an interesting phenomenon. As you can see there are many peaks and troughs throughout this run. These large variations are not expected, and we are not sure as to why this occurs. It seems to build up a network and then breaks and reform again. It was thought that these variations are due to mechanical errors associated with the equipment. We decided to do a run without any flour in the bowl and the result is show in *Figure 2*. No conclusive decision has been made yet as to why these variations occur, but collaboration with Feather Engineering will be made to try to solve the problem.

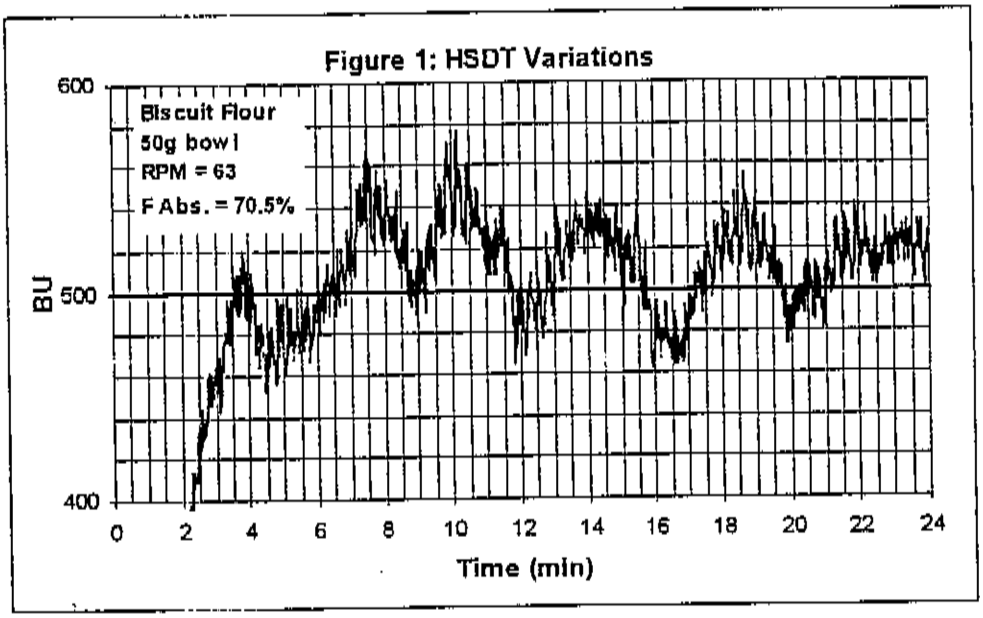
Figure 1: HSDT Variations
Biscuit Flour
50g bowl
RPM = 63
F Abs. = 70.5%
BU
600
500
400
0
2
4
6
8
10
12
14
16
18
20
22
24
Time (min)

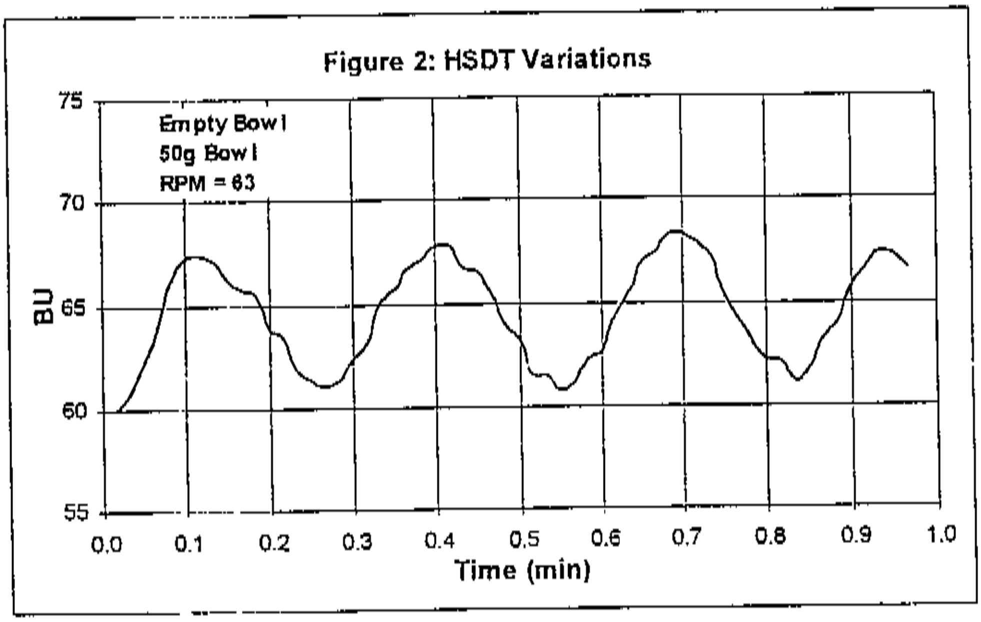
Figure 2: HSDT Variations
Empty Bowl
50g Bowl
RPM = 63
BU
75
70
65
60
55
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
Time (min)

Vanessa Yu and Kate McDonald (Combined)

(a) Analysis of within- and between Paddock Variation in Sprouting
(b) Suitability of WheatRite Test to Monitor Pre-harvest Sprouting in Barley
(c) Assessing grower responses to a new test for preharvest sprouting

Supervisors: J. Skerritt, R Heywood, CSIRO Plant Industry

Final Report

QWCRC Summer Vacation Scholarship Students
Supervisor's report on completion of the scholarships

Supervisor: Mr Russell Heywood
Students: Ms Vanessa Yu and Ms Kate McDonald

Overview

The two students spent the majority of their time assisting with the generation and preliminary analysis of data relating to further development of the "Wheatrite" field test for preharvest sprouting. Initially, the students were introduced to the principles of the ELISA test and observed the process of raising monoclonal and polyclonal antibodies in the rabbits and mice used by the program for a range of projects already underway. This included the injection of antigen, bleeding etc.

They assisted in three main parts of the project
1. analysis of within- and between paddock variation in sprouting. In this project the students specifically subsampled test wheats, ground the wholemeal flour, and extracted and tested using the standard test kit procedure for the card version of the test. Tested cards had the indicator strip removed for analysis using the laboratory method of scanning on the Hewlett Packard Scanjet 6100 C and analysed using the Phoretix 1 D Standard software. In all around 2000 tests were conducted and subsequent data generated by the two students. Areas of specific effort for which the students undertook the majority of the testing and data generation were for the New Zealand, Queensland and Western Australia paddock sampling phase of the project. Finalisation of the results of analysis of the data is now underway.

2. Analysis of the suitability fo the test for monitoring pre-harvest sprouting in barley. The students undertook preliminary testing on barley samples to assist with assessing the application of the Wheatrite test to preharvest testing of barley.

3. Assistance with tabulation of growers' responses to a collaborative trial and survey.

The students provided significant laboratory and field assistance of value to the work of the laboratory in other QWCRC projects including assisting with preliminary cleaning, sampling and testing of harvested samples for the Prime Hard in the South project and the Precision Agriculture project.

Approach

Both students acquitted themselves most satisfactorily over the period of the scholarships. Both demonstrated a very favourable attitude to their duties. Once showed the method of approach to a task they tacked their work with enthusiasm and diligence, with minimal requirements for continuing supervision. Data output was good and consistently of a high standard over the period of the summer scholarship with both showing a genuine interest in the progress of the project. Both showed good self-motivation, approaching their supervisors to seek further information or to gain further work.

Summary

The two students gained a good appreciation of the workings of our laboratory. Both have gained experience of great value to them in the further development of their career paths - one is undertaking a coursework MSc in 1999 and the other is completing her food technology BSc. Additionally the two summer vacation scholars have had a significant effect on reducing the research workload remaining in the Wheatrite test kit project.

Report for Clare Johnson QWCRC
Prepared by Kate McDonald & Vanessa Yu
CSIRO Plant Industry, Canberra.

During our time at CSIRO Black Mountain, Canberra we participated in the development of the QWIP WheatRite prototype preharvest sprouting test. We worked on all aspects of the project from grinding the harvested wheat to running the test strip. We were involved in aspects surrounding other projects as well, in order to understand the concepts behind these and others that were being undertaken at the time at CSIRO.

We used the WheatRite test in both monoclonal and polyclonal antibody forms in duplicate to test the ground samples. The test required us to use laboratory techniques in order to create controlled conditions. Mettler AE 100 scales were used to 4 decimal places to accurately weight out samples and pipettemans were used to measure extraction solution and the test solution, timers were also used. Test strips were kept and scanned using a flatbed scanner onto the laboratory's computer. They were analysed using computer software, Phoretix 1D Standard. This measures the analysis of reflectance and allowed us to do a manual base line correction in order to define the area under the peaks produced from the dark bands on the test strip. The WheatRite test utilises ground samples, so samples to be tested in this way were ground using a Jupiter flour mill in to small labelled vials. Samples from New Zealand were ground in quarantine so no cross contamination could occur with local wheat.

The above was the process we used from beginning to end on the preharvest sprouting test. The test was also evaluated for its potential use on barley using samples from NSW and WA. They were treated in the same manner as wheat in order to see how similarly it reacted. The outcome is currently being evaluated. As part of the field trial farmers were given a questionnaire to gauge their feelings on the usefulness of the test and any suggestions for improvemements to the test. Farmer responses were recorded and followed up.

As well as the Wheatrite project we participated in several other CRC projects. We prepared bags for harvest of experimental plots at Ginnindera Experiment station. This was later followed by unloading harvested samples from Roma, Narrabri, Ariah Park, Walpeup, and Western Australia. After packing them onto pallets we proceeded to record the weight of each bag . The samples were then threshed using the "Steiger". This removed most of the husk, stem and awns. After threshing came cleaning of the unclean sample using the "Seed-Master". Both these techniques required hearing and face protection and were easily mastered after a number of samples. We then sub-sampled the grain into small brown bags. Whilst doing this we analysed the grain using the NIR (Near-Infra-Red) Machine which measured the percent protein and moisture in the sample. The NIR machine was set to take four readings of each sample and then calculate the average which we recorded for later analysis. The sub-samples were then taken back to the lab at Black Mountain. Some of the samples obtained from WA and Queensland from the field sampling side of the Wheatrite project had required them to be grouped into lots of 5, 10 and 50 heads which were then threshed individually on site at Black Mountain.

Some samples required us to measure the "Thousand Kernal Weight" and the density of the grains using the Chondrometer.

In addition we were shown "Ascites" technique on lab mice which involved injecting the abdominal cavity with a chemical, pristane in order to prepare the mice for antibody production. We also witnessed rabbits being bled. Other activities that we participated in included maintenance of the glasshouse which involved daily watering and harvesting of the wheat. Day to day laboratory activities such as cleaning and reorganising lab space and cold rooms was also done.

We found our time at CSIRO Black Mountain educational and enjoyable. John Skerritt and Russell Heywood were both excellent supervisors. Their enthusiasm for the project provided us with a great working environment which encouraged us to work harder. We would like to thank QWCRC for the opportunity to work on such a project which was interesting to both a Food scientist and Biotechnologist. Our time here gave us an insight to scientific research which will be beneficial to our careers in the future.

Thanking You,

Kate McDonald Vanessa Yu

Chris Moore

Breeding Soft Biscuit Wheats for the Northern Wheatbelt

Supervisor: Lindsay O'Brien,
I.A. Watson Grains Research Centre, Narrabri

Interim Report

PROJECT PROGRESS REPORT

This is the first of two reports that are to be written as a requirement of the 1998/99 QWCRC summer vacation scholarship. Following successful application, I was awarded a position with the project "Breeding soft biscuit wheats for the northern wheat belt" at the I.A. Watson Grains Research Centre (IAWGRC) near Narrabri, NSW. Under the guidance of centre director Dr Lindsay O'Brien and soft wheat breeder Dr Shakir Shah, I began work on this project in December, 1998. Since that time, I have experienced many aspects of the soft wheat breeding program associated with the breeding and selection of new wheat varieties. The aim of this report is to review and describe my involvement with the project to date.

During my time with this project, my experiences have been many and varied. Essentially my activities can be divided into the following four main areas:

i) Sowing
ii) Harvesting
iii) Milling
iv) Data Analysis

SOWING

I was very fortunate to experience this activity with the sowing of an off-site trial near Numurkah, Victoria. Owing to climatic conditions, wheat crops cannot be grown to maturation in the Narrabri region during the summer months, hence the need for a suitable off-site location. The summer sowing (commonly referred to as a 'summer nursery') is used to shorten the length of time between filial generations in the breeding program. After organisation and packing, nearly two thousand experimental lines of preliminary yield trials were sown in Numurkah in early December, along with seed increases of advanced breeding lines. With the aid of irrigation, the summer nursery material will be harvested and readied for sowing in winter experiments at Narrabri.

HARVESTING

As I began the project in early December, most harvesting of experimental material in Narrabri was already completed. Several trials at Numurkah, Coleambally and Forbes had yet to be harvested however, and so I was fortunate to experience this activity in early December. Harvesting is probably the most physically intensive operation associated with wheat breeding, a fact made no less easier by the scorching temperatures of the Australian summer. Following harvest, the grain is then cleaned (if necessary) through the use of a dockage tester to remove unwanted plant and foreign debris so that the grain yield can be determined. Grain yield is one of the most important agronomic features of the wheat crop, and is one of the primary selection characters in breeding programs. Following weighing, the seed was then stored awaiting selection for further tests. Additional to the machine harvesting, hand harvesting of some materials was also performed to observe other differences (such as dry matter production and single-head grain production) between selected experimental lines.

MILLING

The milling characteristics of soft biscuit wheats form another important part of the basis for selection of breeding lines. This is a result of pressure from biscuit manufactures to provide cultivars with specific and specialised milling characters, particularly those for flour yield and flour colour. I was given the opportunity to mill some of the 1998 experimental winter lines at Narrabri, using a variety of mills and techniques. A wholegrain mill was used for simple grain crushing and protein analysis using Near Infra-red Spectrophotometry (NIR). For more specialised milling characters, Quadrumat Junior and Senior mills were used to remove unwanted bran and germ by sieving. The Junior and Senior milled samples can then be used for protein analysis using NIR, computerised flour colour analysis, and weighed accurately for flour yield. As a requirement of Junior and Senior milling, I was also familiarised with the process of conditioning (or tempering) so that the moisture levels of the milling samples was standardised. Also of importance for Junior milling is the maintenance of both mill and room temperatures at a constant level.

DATA ANALYSIS

There are several main features to this activity. Of primary concern, is the need to organise and present data collected from milling and harvest in a form that aids selection of experimental varieties with the potential for release commercially, or as breeding lines for favourable traits. There are many different ways in which this may be achieved, and I have been able to experience several of these. The personal computer is the main tool necessary for this task, as statistical programs such as Genstat, Minitab and Agrobase allow fast manipulation and analysis in a number of forms. Typically, analyses of variance (ANOVA's) are performed on the experimental results for one or characters at a time, for example; grain yield, flour yield and flour colour. This analysis compares these characters within the experimental lines, and ranks lines on the basis of having desirable values for those characters. In an attempt to remove variation between lines that is not attributable to genotype, specialised functions such as the Nearest Neighbour Analysis in Agrobase, and the Similarity Dendrogram in Minitab provide useful assistance for the selection of suitable breeding lines.

SUMMARY

'Breeding soft biscuit wheats for northern wheat belt' has been an exciting introduction into the activities and processes of a modern wheat breeding facility. Throughout my time with the project I have been afforded every opportunity to experience every aspect of the soft wheat breeding program at IAWGRC, thanks to the efforts of Dr O'Brien and Dr Shah, and the QWCRC summer vacation scholarship. I eagerly look forward to my remaining time with the project.

Chris Moore

4th February 1999

Chris Moore

Breeding Soft Biscuit Wheats for the Northern Wheatbelt

Supervisor: Lindsay O'Brien,
I.A. Watson Grains Research Centre, Narrabri

Final Report

BREEDING SOFT BISCUIT WHEATS FOR THE NORTHERN WHEAT BELT

Compiled by **Chris Moore**
as a requirement of the
1998/99 QWCRC
Undergraduate Vacation Scholarship

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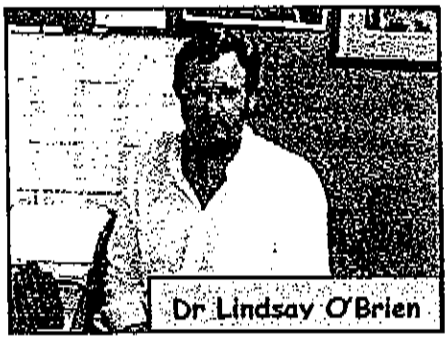
1. BACKGROUND

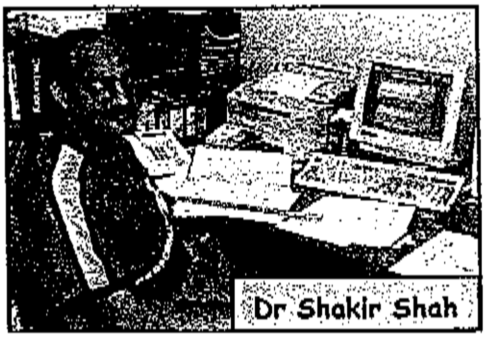
This report has been complied following the recent completion of the 1998/99 undergraduate vacation scholarship project entitled *'Breeding soft biscuit wheats for the northern wheat belt'* with the Quality Wheat Co-operative Research Centre (CRC). The project was undertaken at the I.A. Watson Grains Research Centre (IAWGRC) near Narrabri, New South Wales. I began work on the 10 week project in early December 1998.


Chris Moore

I am a 21-year-old currently progressing into the fourth year of a Bachelor of Science in Agriculture (BScAgr) degree at the University of Sydney which I began in 1996. My primary motivation for undertaking tertiary study was to become a plant breeder of broad-acre crop species. In support of this, I have chosen to major in genetics in my degree, and undertaken vacation scholarships with the CRC for Quality Wheat (1998/99) and the CRC for Sustainable Cotton Production (1997/98). One of my major career ambitions is to seek postgraduate studies in the field of plant breeding following successful completion of my degree.

The aim of this report is to discuss in detail my activities and experiences throughout the course of the QWCRC project at the IAWGRC. Throughout this project I was under the guidance of centre Director Dr Lindsay O'Brien, and soft wheat breeder Dr Shakir Shah. During the time that I spent with this project, I was introduced to a wide range of modern methods and techniques used to test and select suitable soft wheat cultivars suitable for commercial release in the northern region.


Dr Lindsay O'Brien


Dr Shakir Shah

Primarily this project was concerned with the selection of experimental soft biscuit wheat lines for the northern wheat belt (northern NSW and southern Qld), based on requirements supplied to the breeder from growers and biscuit manufacturers (eg. Arnott's Biscuit's Ltd.). Growers of these wheats demand high yielding cultivars that are resistant to the three major forms of cereal rusts (stem, leaf, and stripe) that can occur in the region. Typically, soft wheat varieties that are grown in the southern parts of NSW are not resistant to these rusts, hence the need for a soft wheat breeding program for the northern wheat belt.

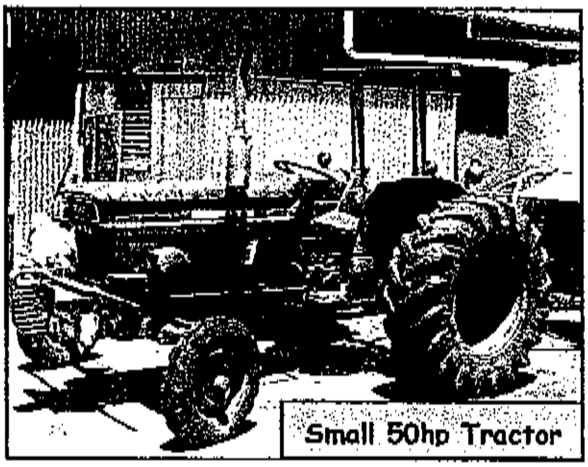
As a result of the introduction of the rust resistance genes through conventional breeding programs, other factors such as the milling qualities and grain yields of the new breeding lines are widely varied. Careful selection of the breeding lines is therefore necessary to select for rust resistant, high yielding cultivars with milling characteristics that are exceptional or (at the very least) acceptable. The remainder of this report discusses (with several examples of my work from the project), the methods and activities used for the successful selection of suitable soft biscuit wheat cultivars for the northern wheat belt from 1998 Advanced Yield Trial 1 (AYT981). This trial features the most advanced commercially viable cultivars from the soft wheat program.

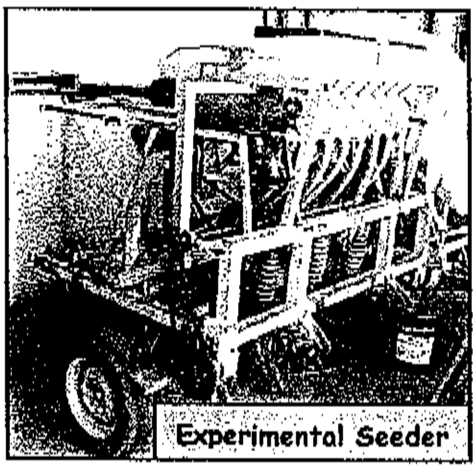
2. SOWING

Typically wheat is not grown in Narrabri during the summer months as plants fail to undergo vernalisation and reach maturation due to the extremely hot climatic conditions. As part of this project however, I was able to experience this activity at an off-site trial in Numurkah, Victoria. It is possible to obtain crop growth and maturation in this region of Australia under irrigated conditions, and as such the Numurkah trial was used as part of the strategy to reduce the amount of time necessary for a new cultivar to be selected and commercially released.

Commonly referred to as the summer nursery, the summer sowing is designed to provide a means of continuing the breeding program at a time when it would generally be impossible to grow a crop in the Narrabri region. Although Narrabri is in a region of NSW which experiences a summer dominant rainfall pattern, it is the temperature constraint which creates the need for a more favourable environment for summer wheat cropping.

Planning for the sowing of the summer nursery provided excellent insight into the many factors that must be considered before any seed can be sown. The importance of these preparations was highlighted by the location of the off-site trial. Numurkah, near Shepparton in Victoria, is over 900km from Narrabri. This distance greatly increased the logistical nature of sowing the summer nursery. Of primary concern was the transportation of the machinery needed for the sowing operation, as well as the pre-emptive planning for all materials that may be required. Further to this, the lines selected for planting had to be readied for sowing following consideration of the land area available and the machinery used. In this instance, the grower defined the land available and identified irrigation constraints to land use. A 50hp tractor was used in conjunction with a small experiment seeder similar to those pictured below, for sowing of the summer nursery.





Fortunately the grower was able to procure a tractor which greatly reduced the stress on the resources necessary for the trip. Transportation space available for this exercise was severely restricted by the harvesting operations which were also to take place on this trip (see following section). Two thousand experimental lines were sown at the site in early December, as well as several bulk advanced line increases. The experimental lines were part of a preliminary yield trial in which lines that exhibited rust resistance, high grain yield and favourable preliminary milling quality traits, would then be selected for entry in advanced yield trials and quality testing. Typically each trial has its cultivars replicated three times, to reduce environmental variation and improve the power of statistical analysis. The sowing of the off-site trial at Numurkah is similar in all respects to those operations undertaken in Narrabri during the winter/spring growth season.

3. HARVESTING

Although most of the harvest was completed at the time I began this project at the IAWGRC, I was fortunate to experience the complete operations and procedures involved as part of the off-site trials of the soft wheat program. The harvesting of off-site trials was carried out in Numurkah (in conjunction with the sowing operations), Coleambally and Forbes. Since soft wheats are widely grown in the wheat belt of southern NSW, these sites were used as a comparison of the performance of the cultivars grown in Narrabri.

Plot Harvester

Unlike harvesting of large bulk areas of grain in conventional wheat enterprises, the harvesting of experimental plots is a much more intensive operation, in terms of both time and resources. Specialised plot harvesting machines are used to harvest small areas (approx. 2 × 4m) at a rate varying anywhere between 40 and 100 plots per hour. The rate at which plots can be harvested depends on many factors, including the state of the crop (eg. lodging), ground condition, the reliable operation of machinery, and the efficiency of the machine operator and support staff. Other factors that may influence harvesting rates are climate and equipment maintenance.

Once the machine has harvested the grain, each plot is then separately bagged and labelled. Following harvest, the grain is removed from the field and stored in a large shed ready for weighing and testing.

Before the harvested material undergoes further testing, it is important that all trials at the site have been harvested. Failure to do so may result in partial or misrepresented results, typically due to weather damage. This is particularly important in the northern wheat belt, as a result of the summer dominant rainfall pattern. Rainfall following full maturity can often lodge the crop making it difficult to harvest, or the grain may sprout in the heads rendering the grain useless.

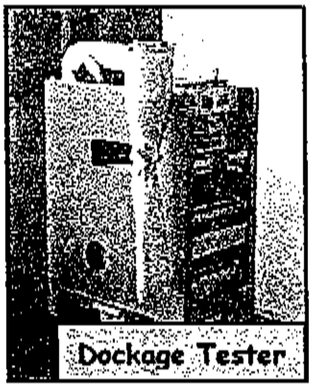
Storage Shed

3.1 WEIGHING

After harvest, the grain is used for a variety of different functions. Some seed is used for sowing in either summer nurseries or in trials in following years. Remaining stocks are used for testing and analysis, or stored as germplasm.

Before the grain from each plot is separated for these uses however, a major agronomic trait of each cultivars is measured. Plot grain yield weights are recorded using electronic scales. Grain yield is an important indicator of the relative performance of each individual cultivar.

Before weighing can take place, it is often necessary to remove unwanted material from the grain. This can be plant material such as straw and husks, or other foreign objects such as weed seeds or soil. Cleaning is an important operation in order to achieve accurate plot grain yields. Inaccurate weights can lead to biasing of material that in general would not perform as well. The dockage tester is a machine that is often used for cleaning experimental plot material.



Once the grain is ready, the grain yield for each plot is weighed and recorded. Result recording is done in one of two ways. The weights can be recorded by hand and then transferred to the computer for analysis, or the weights can be entered directly for the scales into the computer. This can be done with the aid of a barcode reader which records the plot identifier, the plot number, while the scales transfer the grain weight to the computer. The direct entry method of the barcode reader has two main benefits – there are no mistakes regarding the assigning of the plot identifier to each weight; and the process is completed in less time, reducing labour requirements.

An example of raw grain yield weights has been included in the Appendix (I) of this report 'Plot Grain Yields – Steam Bread Trial'. Typically these results will then be converted to tonnes per hectare and analysed for yield performance.

4. MILLING

Since the flour properties of soft wheats influence the quality of the biscuits, it is important to now consider the milling qualities of the individual cultivars, and their performance relative to industry standards. The standards generally used for comparison in the soft biscuit wheat breeding program are the soft wheats Tincurrin, Tatiara and Bowie, and the hard wheat Sunstate. The soft wheat standards have been chosen for their exceptional milling qualities. The hard wheat has been included for comparison, particularly as hard wheats often form the source of germplasm for the introduction of rust resistance genes.

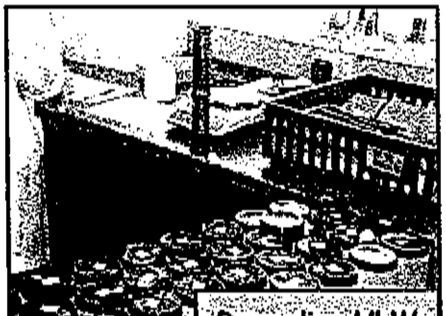
There are several characters that are referred to as milling qualities. These are flour yield, flour colour, and flour protein, as well as dough properties such as dough strength and extensibility, formation time, and breaking point. The following sections of this report discuss these qualities in more detail, and how they are recorded..

Many factors must be managed carefully when milling, in order to achieve accurate results. Mill temperature, room temperature, timing, moisture content and exact procedure repetition are all critical factors governing result accuracy. These too are discussed in more detail in the following sections.

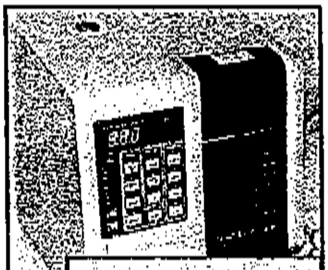
4.I CONDITIONING

Also known as tempering, conditioning is the process that is required by some milling methods to standardise the moisture content of the grain samples prior to milling. Samples milled by Quadrumat Junior and Senior mills require conditioning, however wholegrain milling does not. This is a result of the tests that are applied following milling, and the need to accurately separate the flour fractions. Moisture content will influence the extraction of flour and other milling products to the extent that inaccurate results occur from relatively small moisture content percentage differences. For example, more flour will be extracted from a much lower moisture content.

Before a trial is milled, several measurements of the grain samples are made. These include the grain moisture content, grain density and grain volume. Grain volume is a comparison of seed sizes between the various breeding lines using a fixed volume. The standard volume is the hectolitre, and the grain from this volume is weighed. A example of hectolitre weights (HLW) can be found in the Appendix (II & III) 'Junior Milling – AYT981'.


Recording HLW

Grain moisture contents are determined primarily by one of two methods. The most accurate (and time intensive) method is the use of an oven to dry the grain samples. Weights are recorded prior to and following oven drying, and the difference form the basis of the weight (%) moisture content. An alternative method is the use of moisture tester, which measures the individual grain moisture contents. This method is quicker and less intensive, however the grains from this method are destroyed in the process. The moisture tester counts and uses between 20-5000 seeds, depending on the accuracy needed. Tests have been conducted at IAWGRC to identify the significance of differences in moisture contents between the oven and machine methods; results indicate that these differences are not highly significant.


Moisture Tester

Once the moisture contents are known, they must be adjusted to a standard value. For soft wheat milling, the optimum moisture content is 13%. This is much lower compared to hard wheats, which are typically milled at 15% moisture content. Conditioning of the material is typically required to raise the moisture content of the grain which has dried since harvest. Water is added to the grain samples (calculated as below), which are then shaken on a small table shaker for 30 minutes. The grain samples are then stored at milling temperature of 20°C for 24 hours before the samples are ready for milling.

$$Water\ added\,(ml) = \frac{Sample\ weight\,(g)}{(100 - Desired\ content)} \times (Desired\ content - Moisture\ content)$$

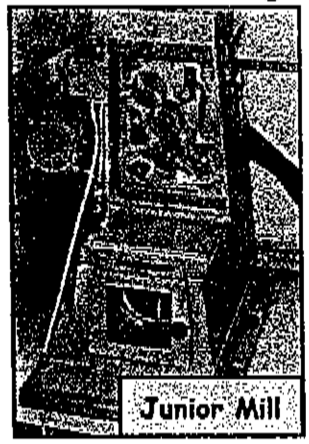
4.II WHOLEGRAIN

Wholegrain milling does not require that grain samples be conditioned. Wholegrain milling is used as a method of supplying flour for fast analysis of flour protein and moisture content using Near Infra-Red (NIR) Spectrophotometry. The results of this test are assumed to be representative but inaccurate of the actual flour protein and moisture contents. These tests are inaccurate owing to the fact that the bran and other unwanted materials are not separated from the flour.


Wholegrain Mill

4.III Junior Mill

The Quadrumat Junior mill incorporates the use of a break/reduction mill and a rotating cylindrical sieve to provide separation of bran and pollard from the flour. The 4S sieve used in soft wheat milling is much coarser than the 7N sieve used for hard wheat milling, owing to the 'fluffy' nature of the larger flour particles in soft wheat flour. The Junior milling process requires the conditioning of samples before milling; subsequently more detailed analysis of the flour can be carried out. Quantitative measures such as flour yield, colour, protein and moisture and the dough properties can be measured.


Junior Mill

Since flour extraction is temperature dependant, it is important to standardise the temperature of both the mill and the room. Each sample is weighed to 100 grams for milling, with each sample taking approximately 7 minutes to complete. Included in this time is the mill clean down, during which flour is flushed from the mill while running.

Due to the temperature constraints, only approximately fifty samples can be milled each day. Each set of fifty samples is called a batch, ie. each batch equals one day. It was found during familiarisation (explained below), that temperature fluctuations are reduced if the batches are milled in one complete run, with no breaks. Stopping the mill for a break allows it to cool, despite the temperature control unit used to keep it at a constant temperature. Both the mill and room temperatures requires constant attention to keep them in the optimum range of 19-21°C.

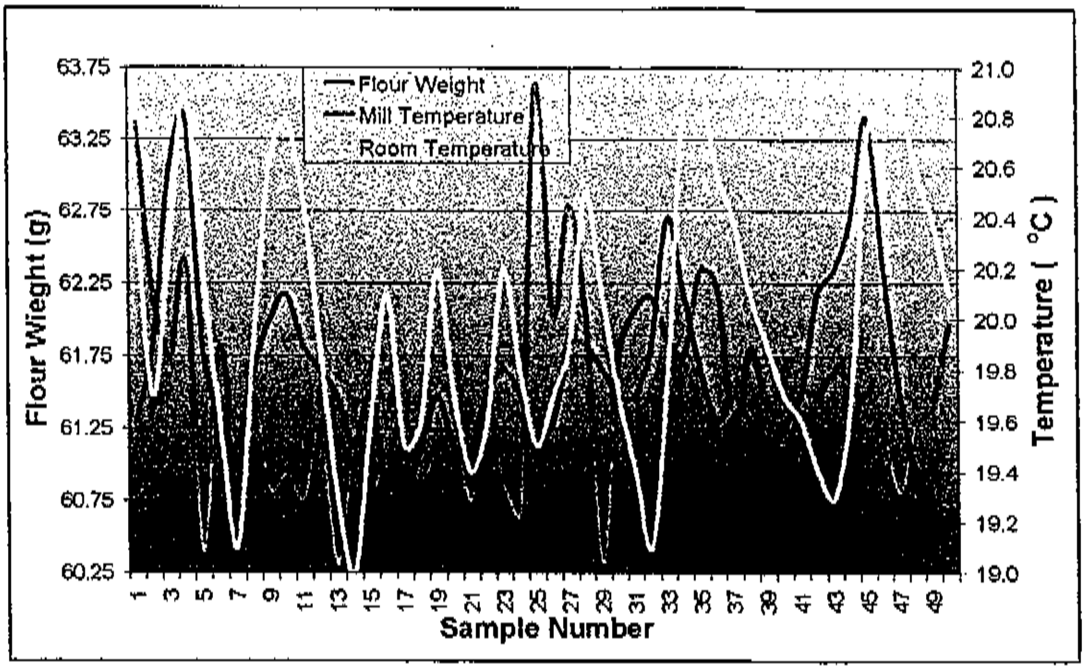
Familiarisation is the term used to describe learning Junior milling operations. The familiarisation is completed by all people who have no prior experience with either Junior or Senior mills. The familiarisation period is used to ascertain the user's ability to replicate results within a reasonable degree of accuracy. The theory behind this is that if the user can accurately replicate results, then their operating procedure is sound, since any variance is attributable to error or change in procedure.

One cultivar (Sunstate) was used for familiarisation, milled in 50 samples in each of three batches. Since I had no previous experience with milling, my familiarisation results are supplied below and in the Appendix (IV) under 'Junior Mill - Familiarisation'. Table 1 (below) shows the grand means and standard errors for flour weight, mill temperature and room temperature of each familiarisation batch. Figure 1 (over page) shows the flour weights of each sample in Batch 1 with respect to temperature of the mill and the room. Following successful familiarisation, several experiments were milled with the Junior mill. Results of AYT981 milling can be found in the Appendix (II & III) 'Junior Milling – AYT981'. Note in the appendix the milling standards (in red) are used to track the variance of procedure and conditions; the ten experimental lines supplied from Wagga (in blue) were not used for more detailed analysis; the control cultivars are shown in green.

Table 1: ***Junior Milling Familiarisation - Means & Std Deviation***

	Batch 1	*Batch 2*	*Batch 3*
Mean Flour Wt (g)	61.49	62.06	61.39
Standard Deviation	0.70	0.60	1.12
Mean Mill Temp (°C)	19.80	19.92	20.01
Standard Deviation	0.35	0.45	0.39
Mean Room Temp (°C)	19.99	19.95	19.93
Standard Deviation	0.54	0.45	0.42

Figure 1: *Junior Milling Familiarisation - Flour Weight & Temperature*



4.IV Senior Mill

The Quadrumat Senior mill is in most respects very similar to that of the Junior mill (including sample conditioning), however it does have its advantages and disadvantages. The Senior mill has three separate stages of grain milling. Grain is fed through a brake mill similar to that of the Junior mill. The product is then sieved through a variety of flat screens to separate bran, pollard and flour. Then pollard and flour is then conveyed back to a reduction mill, for crushing this mix. This product is then fed through another set of finer screens to final separate the flour from the pollard. Flour, bran and pollard are collected in small containers at the bottom of the mill.

Temperature is not critical in Senior milling, and sample sizes are generally in the order of 1 kilogram as opposed to the 100 grams of the Junior milling process. Since larger amounts are milled, each sample can take up 1 hour with greater flour weights. This means that the flour can be used for more tests, including those undertaken following Junior milling, as well as others such a baking properties and replicated tests (eg. colour, protein). Senior milling also has the major benefit of finer degree separation of milled products, through the use of the reduction mill and multiple stage sieving.

Time per sample is by far the greatest disadvantage of Senior milling. With an average of 15 samples being possible each day, it is typically not plausible to mill large experiments. For this reason, generally only the most advanced selected lines are used in Senior milling.

I was fortunate to experience Senior milling of several hard wheats used for noodle making. Table 2 (over page) shows the milled product composition used for noodle benchmarking. Banks, Sunstate and Sunco were the cultivars grown at three separate sites is NSW. More detailed results including milled component weights and moisture contents of this milling are shown in the Appendix (V) 'Senior Milling – Noodle Benchmarking'.

Table 2: *Senior Milling - Milled Components*

SITE	CULTIVAR	FLOUR (%)	BRAN (%)	POLLARD (%)
Moree	Banks	72.22	20.99	2.60
	Sunstate	71.90	20.60	3.23
	Sunco	75.87	21.48	2.66
Gilgandra	Banks	72.63	23.84	3.53
	Sunstate	74.27	20.52	5.21
	Sunco	71.42	25.14	3.44
North Star	Banks	76.37	20.20	3.43
	Sunstate	76.00	20.50	3.50
	Sunco	76.41	20.76	2.83

4.V Flour Yield

Flour is one of the products of milling. Purity of flour (ie removal of bran and pollard) will depend on the mill and process used, for example flour from a Senior mill is more pure than that from a Junior mill, which is more pure than flour from a wholegrain mill.

Flour is the milling product which is used for baking not only in the biscuit making industry, but also that of other industries such as bread, noodle and pasta making. Flour yield is an important characteristic of individual cultivars, as it defines the flour extraction efficiency. Clearly there is a desire from biscuit making industry to maximise flour extraction efficiency through high flour yields.

Flour yield is a percentage function of flour weight, defined by the following equation:

$$Flour\,Yield\,(\%) = \frac{Flour\,Weight\,(g)}{Initial\,Sample\,Weight\,(g)} \times 100$$

It is important to note that the initial sample weight is the sum of the sample grain weight *and* the weight of moisture added through conditioning.

Table 3 (below) shows the grand mean of experimental flour yields, in comparison with the control cultivars from the AYT981 experiment. A full list of flour yields for the AYT981 experiment can be found in the Appendix (II & III).

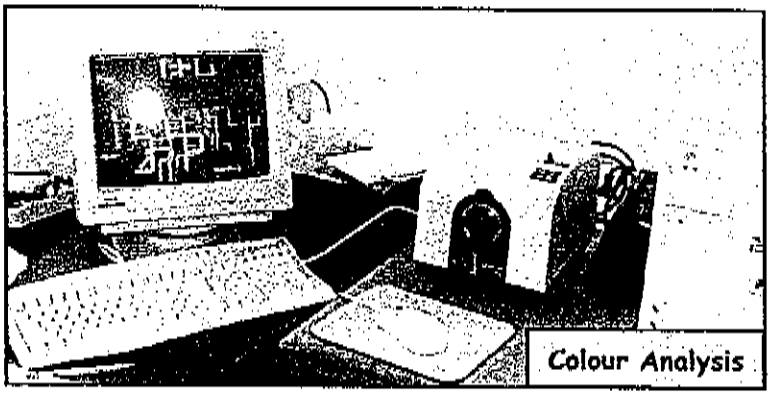
Table 3: *Flour Yields - AYT981 Grand Mean*

EXPERIMENTAL LINES	
Mean Flour Yield (%)	66.4
Standard Deviation	2.6
CONTROL FLOUR YIELDS (%)	
Tincurrin	64.3
Tatiara	66.5
Sunstate	76.8
Bowie	69.4

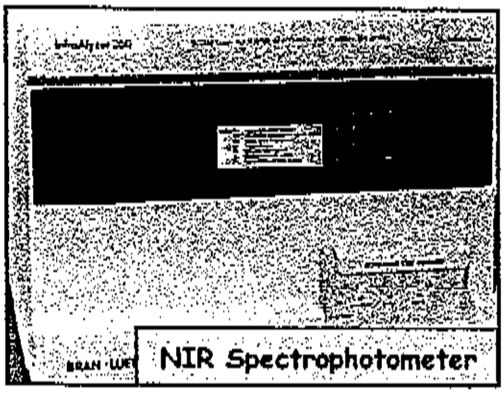
4.VI COLOUR & PROTEIN

Flour colour and protein are also important flour characters that can influence quality biscuit making. Flour colour will ultimately influence the final colour of the biscuit – for this reason a flour that is as white as possible is required. Flours that exhibit poor colour characteristics are typically yellow. Flour protein content can influence the baking properties of the dough in the finished product, for example a biscuit that crumbles too easily.

Both colour and protein analyses are computer automated. Colour analysis is performed by a small machine (below) connected to a standard personal computer. Approximately 30g of flour is placed in the colour analysis machine, which then examines the flour colour. The results are then processed in the computer using dedicated software, and a standard L-a-b colour score is displayed.



Colour Analysis



NIR Spectrophotometer

Using the same 30g flour sample, a Near Infra-Red (NIR) Spectrophotometer (above) is used to analyse the protein content of the flour. The results are shown on a small digital display and recorded by hand. Both of the methods have the advantage of using only a small amount of flour. This leaves adequate flour left for replicate testing is case of unusual values, or for testing additional attributes, such as the dough properties using the mixograph. Testing of both properties takes approximately 5 minutes per sample.

In order to get accurate results, flour purity is an important point. Since both of these tests use colorimetric techniques, bran and other impurities will significantly increase the inaccuracy of any measurements made. For this reason Junior and Senior milled flour can accurately be used, however wholegrain milled flour cannot.

Tables 4 & 5 below show the grand mean experimental colour and protein results in comparison with control values from the AYT981 experimental data set. Full data sets for the colour and protein values from AYT981 can be found in the Appendix (II & III).

Table 4: *Flour Colour - AYT981 Means*

EXPERIMENTAL	L	A	B
Mean Colour Value	93.9	0.2	8.2
Standard Deviation	0.3	0.1	1.0
CONTROLS			
Tincurrin	94.0	0.1	8.8
Tatiara	93.6	0.2	10.8
Sunstate	92.5	0.5	11.8
Bowie	93.5	0.2	10.9

Table 5: *Flour Protein - AYT981 Means*

EXPERIMENTAL	
Mean Protein %	9.9
Standard Deviation	0.9
CONTROLS	
Tincurrin	8.8
Tatiara	10.8
Sunstate	11.8
Bowie	10.9

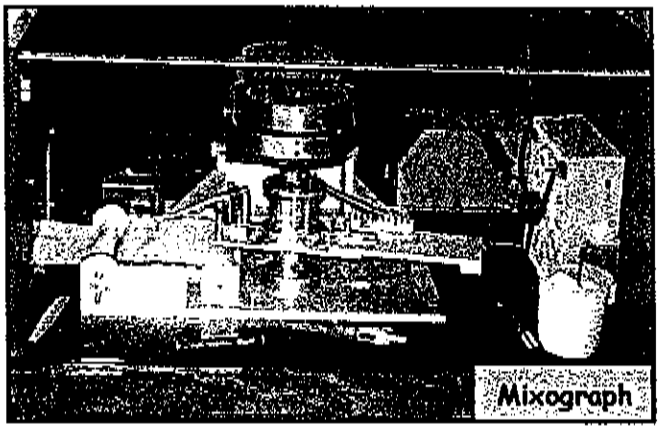
4.VII Mixographs

The mixograph is used to define the physical properties of the dough. These characteristics are also of importance to the biscuit manufacturing industry. Dough properties that are measured by mixographs are dough stability time, dough formation (development) and breakdown time, peak height, and band width.

The mixograph works by measuring the resistance generated when forming a dough from a simple flour and water mix. The amount of water added for dough formation is calculated as the estimated optimum water absorption (EOWA) using the following formula:

$$EOWA\,(\%) = 1.5 \times (\text{Flour Protein Content }\%) + 43.6$$

Each of the dough characters are important, as they impact the dough making process to varying degrees. Dough formation time is important for example, because as with any industry, time is related to cost of production. Ideally a dough should form quickly, have optimal strength but not deteriorate too quickly. Each mixograph sample takes approximately 8 minutes.



Dough property testing using the mixograph is a relatively simple procedure, recently aided through the use of computer software which automatically examines the mixograph output. Table 6 below shows the grand mean for each of the dough properties measured in the AYT981 trial, in comparison with the experimental controls. The full mixographs results for the AYT981 trial can be found in the Appendix (VI & VII) 'Dough Properties – AYT981'.

Table 6: ***Dough Property Means - AYT981***

Experimental Lines					
	EOWA (%)	**Formation** (secs)	**Peak Height** (MU)	**Stability** (secs)	**Breakdown** (MU)
Mean	58.42	63	5.6	75	0.2
Standard Dev.	1.36	18	0.6	27	0.1
Controls					
Tincurrin	56.74	50	4.2	110	0.1
Tatiara	59.77	65	5.9	80	0.1
Sunstate	61.35	135	6.2	105	0.3
Bowie	59.91	85	6.5	55	0.1

NB: MU = Mixograph Units

5. Rust Resistance

Once material has been tested, grain samples are sent to the National Rust Control Program at the University of Sydney Plant Breeding Institute (PBI), Cobbitty. At the PBI, the grain samples are screened for resistance to the major rust pathogens common to the northern wheat belt, namely leaf, stripe and stem rust.

It is important to discern which lines carry rust resistance genes so that a new cultivar without them cannot be released in the region. This helps to avoid devastating losses through susceptible cultivars in combination with epidemics of the disease.

Following the results of the rust screening, the breeder has several options. If the line has proven resistance for one or more of the rust pathogens, the line can be further selected and continue in the program. If a line has other valuable traits, such as high milling quality characters but no resistance genes, this line may be placed back through the breeding program as a parent line for those characters. Should a line perform poorly in agronomic and milling testing, resistance screening can serve as a useful selection tool, for example those lines of poor performance and no resistance can be removed from the program.

6. Data Analysis

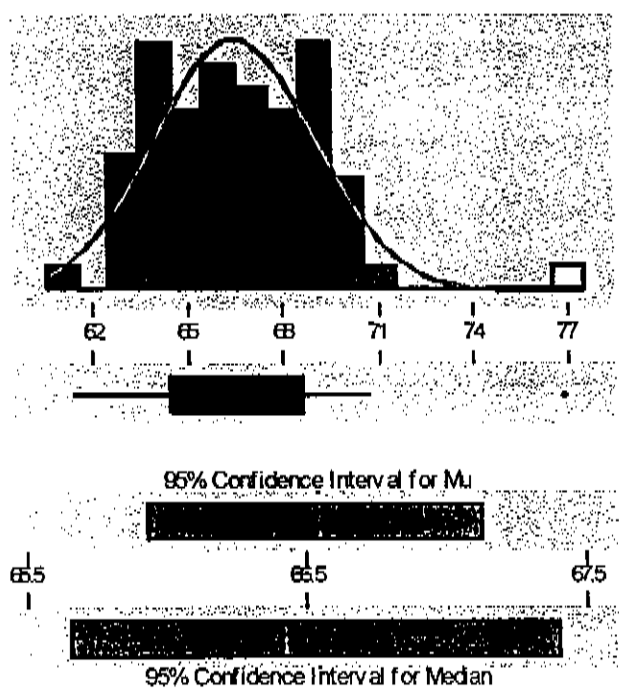
Essentially a tool to aid selection, data analysis is used to clarify differences between cultivars and their performance relative to a set of standards or controls. Essentially this is a statistics based method which attempts to allow the breeder to select lines on the basis of performance of one or more defined characters or traits. These characters typically are those within the individual lines that have been tested throughout the breeding program. For example, agronomic traits such as grain yield and vegetative growth, quality characters such as those of milling properties, and genomic characters such as rust resistance.

Data analysis encompasses a wide range of tasks. Since most statistical analysis of the modern age is aided by the personal computer, data from all the tests and results from the trial must be entered and collated. This can often be a lengthy process, compounded by the requirements of some statistical analysis software. This software will often require the data to be in a particular form before an analysis can be undertaken. Further more, analysis is often undertaken in terms of non-experimental units thereby requiring data conversion, for example plot grain yield is often converted to tonnes per hectare (t/ha). Additional to this, is the need to compare the performance of lines over time, and at different locations.

There are many statistical analysis packages available for the plant breeder. Each of these has advantages and disadvantages in terms of ease of use and relative abilities. Often the software selection will be a choice made by the breeder based on personal preference. In my short time with this project, I have found that using the best features of a small number of packages to be more useful than just any one program. Having more than one software package however can be viewed as a luxury however, as many of these programs have high purchase costs that can range from hundreds to even thousands of dollars. At IAWGRC, I was fortunate to gain experience using several statistical based software packages; Genstat® 5 Release 3.2; Minitab® Release 11.21; and Agrobase™ 97. Microsoft Excel® 97 was the preferred spreadsheet package used for data entry and collation.

An example of a statistical package output is given in Figure 2 (below) by the 'Descriptive Statistics' function from Minitab® Release 11.21. This function is a raw data output, useful for determining the suitability of a data set for analysis. This figure helps to outline the normality of the data set. Should a data set be non-normal, data transformation (such as logarithmic or square root) is required to achieve normality, since most analyses assume normality. Note the hard wheat (Sunstate) outlier in yellow.

Figure 2: *Minitab® Descriptive Statistics - AYT981 Flour Yields*



Variable: Flour Yield (%)

Anderson-Darling Normality Test	
A-Squared:	0.451
P-Value:	0.268
Mean	66.5310
StDev	2.5204
Variance	6.35217
Skewness	0.822407
Kurtosis	2.10707
N	71
Minimum	61.3000
1st Quartile	64.4000
Median	66.4000
3rd Quartile	68.5000
Maximum	76.8000
95% Confidence Interval for Mu	
65.9344	67.1275
95% Confidence Interval for Sigma	
2.1632	3.0199
95% Confidence Interval for Median	
65.6577	67.4000

6.1 Spatial Analysis

Spatial analysis has been included in this report as I found the concept of an Analysis of Variance (ANOVA) based on relative field positioning very interesting. The spatial analysis, such as that offered by the 'Nearest Neighbour Analysis' in Agrobase™ uses the plot field positioning as a variate of the ANOVA. This type of analysis is used to identify another form of variance that would in most other ANOVA's be (less accurately) included in the environmental or error variance.

Cultivars 981-1 through 981-35 from the AYT981 trial are the most advanced breeding lines in the soft wheat program at IAWGRC. Each of these have been grown and selected for the past 3 years at sites in Narrabri and the last two years at many other sites, to provide an accurate picture of their performance in the northern wheat belt.

Table 7 shows the tonnes per hectare grain yields (unadjusted), Agrobase™ 'Nearest Neighbours Analysis' adjusted grain yield values and means for the first 35 cultivars (and controls) of the Narrabri AYT981 experiment in 1998. Appendix (VIII) shows the grain yields (adjusted) for the first 35 cultivars in AYT981 trials at Narrabri, North Star, Moree, and Forbes over the past 3 years. Experiments at other sites have also been undertaken during this time.

Table 7: *Adjusted Grain Yields - Narrabri AYT981 (Advanced Material)*

CULTIVAR	GRAIN YIELD (t/ha)	ADJ. GRAIN YIELD (t/ha)
981-1	2.20	2.76
981-2	3.25	3.10♣
981-3	3.35	3.38♣
981-4	3.35	3.23♣
981-5	3.30	3.47♣
981-6	2.85	3.15♣
981-7	3.25	3.12♣
981-8	1.90	1.99
981-9	3.10	3.19♣
981-10	3.20	3.59♣
981-11	2.95	2.90♦
981-12	2.80	2.88
981-13	3.10	3.04♣
981-14	2.80	3.08♣
981-15	3.05	2.58
981-16	3.60	3.63♣
981-17	2.30	2.73
981-18	3.10	2.88
981-19	3.45	3.73♣
981-20	2.55	2.78
981-21	3.05	3.06♣
981-22	3.20	2.58
981-23	3.00	3.18♣
981-24	3.90	4.02♣
981-25	2.45	2.64
981-26	3.55	3.31♣
981-27	3.65	3.36♣
981-28	2.85	2.99♦
981-29	3.55	3.20♣
981-30	2.95	2.86
981-31	3.25	3.51♣
981-32	3.55	3.63♣
981-33	3.00	2.81
981-34	2.95	2.73
981-35	3.80	3.85♣
Mean	**3.07**	**3.09**
Std Dev.	0.44	0.42
CONTROLS		
Tincurrin	2.95	2.89
Tatiara	2.25	2.45
Bowie	2.55	2.77
Sunstate	2.85	2.99

♦ - Higher grain yield than Tincurrin, Tatiara and Bowie (soft wheat) controls
♣ - Higher grain yield than all controls.

6.II MULTIVARIATE ANALYSIS

The dendrogram, a form of hierarchical multivariate cluster analysis (such as the 'Cluster Observations' function in Minitab®) is another useful tool for cultivar selection. The dendrogram works on the principle of similarity as a basis of grouping within a particular character. For example, it can be used to group similar levels of grain yield, such that high yields are a distinctly separate group from those of lower yields.

However dendrograms can be used to find similarities between many characters at the same time, hence their power of classification is increased. For example, they can be used to classify those lines with similar grain yield, flour yield, flour colour and flour protein. These relationships are much more complicated, and in this way the dendrogram can save the breeder large amounts of time when selecting on the basis of many characters, as is the case with the soft wheat breeding program at IAWGRC.

Figure 3 (below) is an example dendrogram comparing the similarity between characters tested in the Narrabri AYT981 trial. The level of similarity chosen will influence the number of classes and vice versa. This means that if a similarity level of 80 is chosen for example, there are six distinct classes opposed to 3 classes at a similarity of 20. Typically, a similarity level of >60 is used, giving 4-6 classes for an 80 cultivar comparison. For the dendrogram shown below, Table 8 (over page) shows the data and the six groupings at a similarity level of 74.48 for characters of adjusted grain yield, flour yield, flour colour and flour protein. Controls (except Sunstate) have been included for comparison.

Figure 3: Hierarchical Cluster Analysis - AYT981

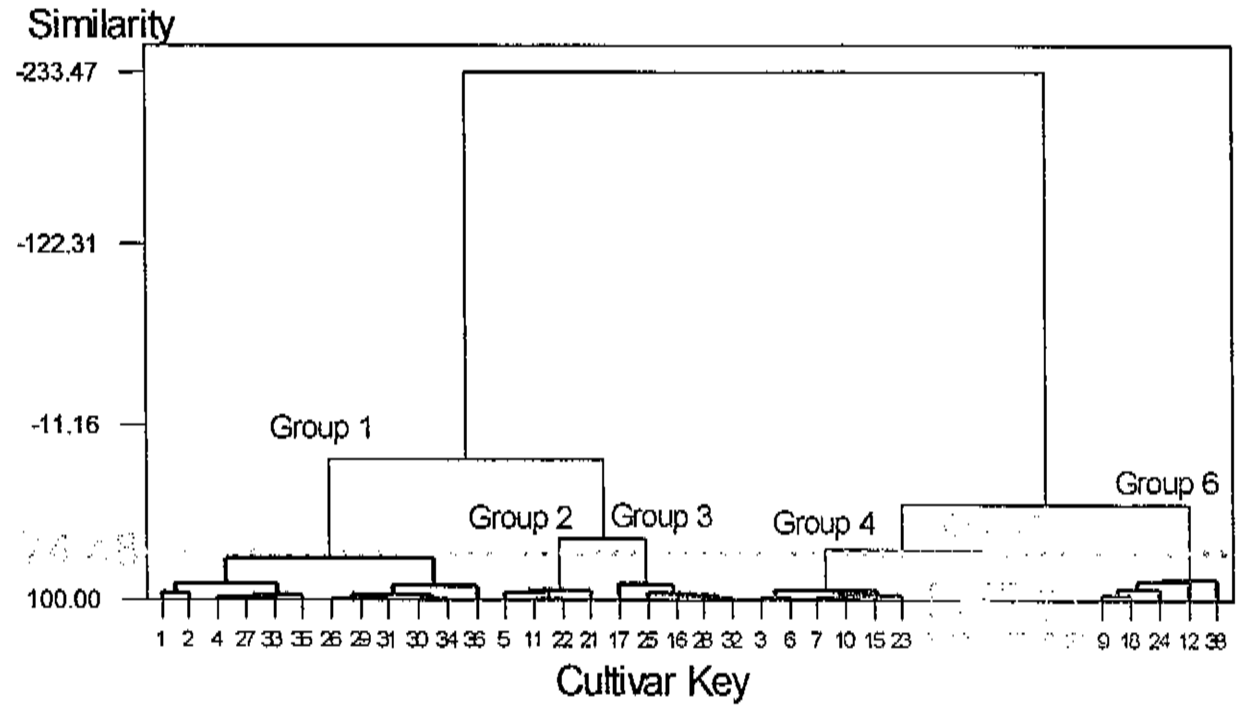


Table 8: *Multivariate Analysis Groupings - Narrabri AYT981 (Advanced Material)*

Cultivar Key	Analysis Grouping	Cultivar	Adj. Grain Yield (t/ha)	Flour Yield (%)	Flour Colour L	a	b	Flour Protein (%)
1	1	981-1	2.76	66.2	94.2	0.2	8.6	9.2
2	1	981-2	3.10	65.1	94.1	0.2	9.2	9.7
4	1	981-4	3.23	65.5	94.2	0.1	8.5	8.1
26	1	981-26	3.31	64.4	93.9	0.2	8.2	8.9
27	1	981-27	3.36	65.2	93.8	0.2	8.3	8.4
29	1	981-29	3.20	64.6	94.1	0.2	8.4	8.6
30	1	981-30	2.86	64.1	94.2	0.1	8.1	8.3
31	1	981-31	3.51	64.4	94.1	0.1	8.5	8.7
33	1	981-33	2.81	65.8	94.2	0.1	8.0	8.4
34	1	981-34	2.73	64.1	94.3	0.1	8.0	8.8
35	1	981-35	3.85	65.9	94.0	0.2	8.1	8.9
36	1	Tincurrin	2.89	64.3	94.0	0.1	6.7	8.8
5	2	981-5	3.47	65.1	94.1	0.2	7.1	10.1
11	2	981-11	2.90	64.8	93.6	0.2	7.2	11.0
21	2	981-21	3.06	66.1	94.0	0.2	7.1	11.1
22	2	981-22	2.58	64.7	93.9	0.3	7.3	10.7
16	3	981-16	3.63	63.4	94.0	0.2	7.3	10.0
17	3	981-17	2.73	63.7	93.7	0.2	8.0	11.5
25	3	981-25	2.64	64.0	94.0	0.1	8.1	10.1
28	3	981-28	2.99	63.1	93.8	0.2	8.4	10.0
32	3	981-32	3.63	63.0	94.0	0.1	8.1	9.5
3	4	981-3	3.38	66.2	94.2	0.2	7.2	9.1
6	4	981-6	3.15	66.3	94.1	0.2	7.5	9.7
7	4	981-7	3.12	66.8	94.0	0.2	8.0	9.4
10	4	981-10	3.59	66.7	94.1	0.1	8.1	9.7
15	4	981-15	2.58	66.8	93.8	0.2	7.8	10.0
23	4	981-23	3.18	67.5	94.3	0.2	7.5	9.6
8	5	981-8	1.99	67.4	94.1	0.2	9.2	9.4
13	5	981-13	3.04	66.6	93.5	0.2	8.9	10.4
14	5	981-14	3.08	66.3	93.4	0.2	8.6	10.4
19	5	981-19	3.73	67.6	93.5	0.2	8.9	10.7
20	5	981-20	2.78	67.4	93.7	0.3	8.7	10.2
37	5	Tatiara	2.45	65.5	93.6	0.2	9.0	10.8
9	6	981-9	3.19	68.8	93.9	0.2	8.8	10.1
12	6	981-12	2.88	68.5	94.0	0.2	7.3	10.2
18	6	981-18	2.88	69.1	94.2	0.1	8.5	9.0
24	6	981-24	4.02	68.0	94.1	0.1	9.3	9.2
38	6	Bowie	2.77	69.4	93.5	0.2	9.3	10.9

Based on yield and milling quality testing of the Narrabri AYT981 soft wheat trial, the above groups have been found by multivariate analysis to be similar for one or more attributes within the group. Using the controls as comparators, lines can more easily be selected for desirable attributes as either an entire group, or as individual lines. The following section of this report outlines the critical considerations when attempting this selection.

7. Line Selection

Experimental line selection for commercial release is the culmination of many years of work breeding a cultivar that is suitable for the environment in which it is to be grown, and exhibits a particular set of traits. In the case of the soft biscuit wheat breeding program at IAWGRC, the cultivars are selected on the basis of agronomic performance (ie grain yield) in the northern wheat belt, and exceptional milling qualities as defined by the biscuit manufacturing industry (equal to those of the cultivars Tincurrin and Tatiara). Further to these requirements, rust resistance for three major rusts must also be present as a precautionary measure.

The selection of lines is perhaps one of the most important decisions that a breeder can make. Incorrect selection will result in a line that is deemed unsuitable by the producers and industry on the grounds of production or processing qualities. Similarly, not selecting a line which has traits superior to the released cultivars, results in a breeding program that does not reach its full potential. It is therefore important that all the relevant aspects of the new cultivars are known – such that with the aid of statistical analysis meaningful cultivar selection can take place.

In the next section of this report, an attempt has been made to select those cultivars from the 1998 Advanced Yield Trial (AYT981) at Narrabri which are potentially suitable for commercial release, in respect to comparative performance to the industry standards of Tincurrin and Tatiara. It is assumed at this point that each of the first 35 cultivars in the AYT981 trial have been successfully screened for rust resistance.

7.1 1998 Selected Lines

The following 12 experimental lines have been selected as potential lines for commercial release as soft biscuit wheat cultivars in the northern wheat belt. They have exceptional grain yields and milling qualities superior to the industry preferred cultivars of Tincurrin and Tatiara.

981-3	981-7	981-12	981-24
981-5	981-9	981-18	981-27
981-6	981-10	981-23	981-35

The following 12 experimental lines have been selected for desirable attributes suitable for further use as breeding lines. Each of these lines exhibit some qualities, either in grain yields or milling qualities, of exceptional standards which warrant their incorporation into future cultivars.

981-1	981-13	981-19	981-29
981-2	981-14	981-21	981-31
981-4	981-15	981-26	981-33

The following 11 lines have been found unsuitable for selection as breeding material or for commercial release. They have no exceptional attributes which warrant further experimentation.

981-8	981-17	981-25	981-32
981-11	981-20	981-28	981-34
981-16	981-22	981-30	

8. General Discussion

The soft wheat breeding program at the IAWGRC has been constructed to establish potential varieties for commercial release in the northern wheat belt. The preliminary objectives of this breeding program were the incorporation of rust resistance genes and regional adaptation of a specific crop that until has not been widely grown in the region.

At this point in time, the IAWGRC has achieved these preliminary objectives. Rust screening has shown the program to produce experimental cultivars with resistance to the three major rust pathogens, and both preliminary and advanced yield trials have proven adaptation to the regional environment. Work undertaken in the program now is now aimed at increasing the relative values of these cultivars, through the selection of cultivars with superior agronomic performance, and exceptional milling qualities.

Although only in operation for a relatively short period of time, the program is already beginning to provide promising cultivars which have the superior traits. Following selection of the most superior advanced lines (such as the twelve mentioned in the previous section), they are then sent to millers within the biscuit industry to finally establish the best milling lines. In order to achieve this, a small variety of suitable lines should be sent, to provide to the maximum opportunity of a successful cultivar. This requires that the breeding program be large enough to ensure this small selection, however, not so that the proportions of the program mean that line selection becomes impossible.

Another important facet of breeding that has become apparent to me throughout the QWCRC program is the need to consult both producers and industry alike, so that a suitable selection can be made. Clearly a cultivar that has the very best milling qualities, but is susceptible to rusts or does not yield well be useless to the producer. The breeder must attempt to satisfy all parties without reducing the overall performance of the cultivar.

I have found this QWCRC-funded project a most rewarding and invaluable experience, especially with respect to the breeding strategies and methods employed for the development of a new soft biscuit wheat cultivar. Throughout this project, I have been afforded every opportunity learn in detail every aspect of the operations of the IAWGRC and the soft wheat breeding program, thanks to centre Director Dr O'Brien, and soft wheat breeder Dr Shah. My time with this project has been most enjoyable, and reaffirmed my decision to undertake plant breeding as an occupation.

I would like to take this opportunity to thank the QWCRC and the IAWGRC for the opportunity to work on the soft wheat breeding program. I strongly recommend any person considering a career of research in cropping species to apply for any vacation scholarships offered by the QWCRC.

9. APPENDIX (I)

PLOT GRAIN YIELDS – STEAM BREAD TRIAL

Treatment Number	Cultivar	Nitrogen (kg/ha)	Replicate 1 (g/plot)	Replicate 2 (g/plot)
1	SUNCO	0	2.176	2.766
		200	2.605	2.306
2	BANKS	0	2.200	1.875
		200	1.576	1.534
3	BATIVIA	0	2.491	2.558
		200	2.571	2.082
4	SUN 109A	0	3.127	3.879
		200	3.239	3.440
5	MATONG	0	2.392	2.157
		200	2.298	2.168
6	OXYEN	0	1.987	1.507
		200	1.511	1.724
7	HALBERD	0	2.360	2.147
		200	2.305	1.895
8	HARTOG	0	2.942	2.416
		200	2.241	2.491
9	+/+ N	0	2.389	1.874
		200	1.512	1.725
10	-/- 4A	0	2.426	1.952
		200	2.038	1.637
11	-/- 7D	0	1.660	2.165
		200	1.648	1.561
12	-/-4A+7D	0	2.316	2.173
		200	1.819	1.605
13	LANCE	0	2.870	2.085
		200	2.098	2.568
14	HERON	0	2.328	1.829
		200	1.696	1.792
15	SCHOM	0	2.735	2.625
		200	2.932	2.439
16	SUNLIN	0	2.649	2.939
		200	2.920	2.891
17	SUNSTATE	0	2.980	2.341
		200	2.219	2.628
18	TASMAN	0	2.478	2.011
		200	1.956	2.353
19	WARIGAL	0	2.545	2.987
		200	2.471	2.446
20	WAXY-TH7	0	1.225	1.567
		200	1.878	1.395

9. Appendix (II)

Junior Milling - AYT981 (Batch 1)

Ave. Moisture Content = 11.4 %				Flour						Temperature	
Batch No.	Mill No.	Cultivar ID	HLW (g)	Weight (g)	Yield (%)	Protein (%)	Colour L*	Colour a*	Colour b*	Mill (°C)	Room (°C)
1	1	Standard	75.1	72.5	71.2	9.9	93.6	0.4	8.3	19.9	19.3
1	2	981-1	73.4	67.5	66.2	9.2	94.2	0.2	8.6	20.3	19.8
1	3	981-2	72.8	66.3	65.1	9.7	94.1	0.2	9.2	20.7	20.5
1	4	981-3	71.5	67.4	66.2	9.1	94.2	0.2	7.2	20.1	20.1
1	5	981-4	71.6	66.7	65.5	8.1	94.2	0.1	8.5	19.9	19.8
1	6	981-5	72.7	66.3	65.1	10.1	94.1	0.2	7.1	19.6	19.4
1	7	981-6	73.8	67.6	66.3	9.7	94.1	0.2	7.5	20.1	20.5
1	8	981-7	72.1	68.1	66.8	9.4	94.0	0.2	8.0	20.2	20.5
1	9	981-8	69.1	68.7	67.4	9.4	94.1	0.2	9.2	20.0	20.1
1	10	981-9	75.2	70.1	68.8	10.1	93.9	0.2	8.8	19.9	19.8
1	11	981-10	73.7	68.0	66.7	9.7	94.1	0.1	8.1	19.9	19.5
1	12	981-11	71.3	66.0	64.8	11.0	93.6	0.2	7.2	20.0	19.9
1	13	981-12	70.2	69.8	68.5	10.2	94.0	0.2	7.3	20.2	20.6
1	14	981-13	71.1	67.9	66.6	10.4	93.5	0.2	8.9	20.0	20.2
1	15	981-14	69.4	67.6	66.3	10.4	93.4	0.2	8.6	19.9	19.9
1	16	981-15	70.9	68.0	66.8	10.0	93.8	0.2	7.8	20.0	20.2
1	17	981-16	69.1	64.6	63.4	10.0	94.0	0.2	7.3	20.1	20.9
1	18	981-17	66.4	64.9	63.7	11.5	93.7	0.2	8.0	19.8	20.4
1	19	981-18	74.3	70.4	69.1	9.0	94.2	0.1	8.5	19.7	19.9
1	20	981-19	74.3	68.9	67.6	10.7	93.5	0.2	8.9	19.8	19.6
1	21	981-20	70.8	68.7	67.4	10.2	93.7	0.3	8.7	20.4	19.4
1	22	Standard	75.4	72.4	71.2	10.4	93.7	0.4	8.1	20.5	19.5
1	23	981-21	71.8	67.4	66.1	11.1	94.0	0.2	7.1	19.3	20.2
1	24	981-22	70.4	65.9	64.7	10.7	93.9	0.3	7.3	19.8	20.0
1	25	981-23	73.3	68.8	67.5	9.6	94.3	0.2	7.5	20.0	19.8
1	26	981-24	75.2	69.2	68.0	9.2	94.1	0.1	9.3	20.1	19.6
1	27	981-25	70.1	65.2	64.0	10.1	94.0	0.1	8.1	20.2	19.5
1	28	981-26	71.2	65.6	64.4	8.9	93.9	0.2	8.2	20.4	19.5
1	29	981-27	71.8	66.4	65.2	8.4	93.8	0.2	8.3	20.1	19.5
1	30	981-28	69.4	64.3	63.1	10.0	93.8	0.2	8.4	20.0	19.5
1	31	981-29	73.7	65.8	64.6	8.6	94.1	0.2	8.4	19.9	19.5
1	32	981-30	72.4	65.4	64.1	8.3	94.2	0.1	8.1	19.9	19.6
1	33	981-31	71.9	65.6	64.4	8.7	94.1	0.1	8.5	19.9	19.6
1	34	981-32	70.9	64.2	63.0	9.5	94.0	0.1	8.1	20.1	19.6
1	35	981-33	72.5	67.1	65.8	8.4	94.2	0.1	8.0	20.5	19.5
1	36	981-34	72.2	65.3	64.1	8.8	94.3	0.1	8.0	20.2	19.6
1	37	981-35	73.2	67.1	65.9	8.9	94.0	0.2	8.1	20.1	19.6
1	38	981-36	75.2	71.1	69.8	10.9	94.3	0.2	5.1	20.1	19.6
1	39	981-37	76.3	72.3	71.0	11.0	94.6	0.2	5.0	20.1	19.7
1	40	981-38	71.8	67.9	66.6	10.7	94.0	0.3	8.8	20.1	19.7
1	41	981-39	71.1	68.2	66.9	10.8	93.9	0.4	8.7	20.1	19.7
1	42	981-40	75.9	78.0	76.5	12.1	92.9	0.5	8.1	20.0	19.7
1	43	Standard	75.2	71.9	70.6	10.0	93.8	0.4	8.1	20.0	19.7

9. Appendix (III)

Junior Milling – AYT981 (Batch 2)

Ave. Moisture Content = 11.2 %				Flour						Temperature	
Batch No.	Mill No.	Cultivar ID	HLW (g)	Weight (g)	Yield (%)	Protein (%)	Colour L*	Colour a*	Colour b*	Mill (°C)	Room (°C)
2	1	Standard	74.8	70.4	68.6	10.7	94.0	0.3	7.8	19.7	20.7
2	2	981-41	73.8	66.7	65.3	11.0	94.0	0.3	7.4	19.3	19.9
2	3	981-42	77.1	73.2	71.7	10.4	93.8	0.4	6.7	19.3	19.4
2	4	981-43	73.9	67.5	66.1	11.7	93.7	0.5	7.5	20.0	19.3
2	5	981-44	75.5	72.5	71.0	8.5	94.2	0.3	7.4	20.3	20.1
2	6	981-45	75.2	67.0	65.6	12.2	93.6	0.3	7.0	20.1	20.4
2	7	981-46	68.3	65.2	63.9	11.0	93.9	0.3	7.3	19.9	19.3
2	8	981-47	69.7	65.7	64.4	8.4	94.0	0.2	7.3	20.2	19.7
2	9	981-48	68.0	64.4	63.0	9.8	93.9	0.2	8.4	20.4	20.5
2	10	981-49	73.7	69.2	67.7	10.2	93.2	0.4	9.3	20.1	20.1
2	11	981-50	70.3	65.4	64.1	11.0	94.0	0.2	8.5	19.6	19.2
2	12	981-51	72.2	67.8	66.4	10.4	93.7	0.2	8.9	20.0	19.8
2	13	981-52	69.6	63.9	62.5	9.8	94.2	0.2	8.0	20.2	20.6
2	14	981-53	74.9	67.1	65.7	9.4	93.8	0.3	10.3	20.0	20.1
2	15	981-54	73.3	66.5	65.2	11.5	93.6	0.4	10.2	19.5	19.4
2	16	981-55	72.5	65.4	64.0	10.8	93.6	0.3	11.2	19.8	19.5
2	17	981-56	75.5	71.4	69.9	10.4	93.9	0.2	7.7	20.1	20.3
2	18	981-57	72.4	70.0	68.5	11.0	93.8	0.3	7.6	19.8	20.6
2	19	981-58	75.1	68.0	66.5	9.6	94.1	0.3	10.6	19.6	19.9
2	20	981-59	71.6	62.6	61.3	10.5	94.0	0.2	9.1	19.4	19.2
2	21	981-60	74.4	71.8	70.3	10.6	94.1	0.3	7.4	19.7	19.3
2	22	Standard	75.2	70.3	68.6	10.2	94.4	0.3	7.9	20.1	20.1
2	23	981-61	73.1	71.9	70.4	11.3	94.0	0.3	7.6	20.1	20.6
2	24	981-62	70.1	70.7	69.2	10.2	94.0	0.2	7.3	20.0	20.0
2	25	981-63	70.8	70.3	68.8	10.3	93.7	0.3	7.7	19.9	19.4
2	26	981-64	69.7	70.1	68.7	9.8	94.0	0.2	7.8	20.4	19.9
2	27	981-65	70.4	70.2	68.8	9.9	94.1	0.2	7.3	20.3	20.7
2	28	981-66	69.4	69.2	67.8	10.5	93.8	0.2	7.7	20.1	20.7
2	29	981-67	69.2	68.9	67.5	10.4	93.8	0.2	7.3	19.8	19.9
2	30	981-68	71.9	72.2	70.7	9.0	94.2	0.1	7.5	19.6	19.4
2	31	981-69	70.5	69.5	68.0	10.5	93.7	0.2	7.0	19.8	19.8
2	32	981-70	73.5	71.0	69.6	9.6	94.1	0.1	6.9	20.0	20.4
2	33	981-71	72.4	70.4	68.9	10.3	93.8	0.2	6.4	19.6	19.8
2	34	981-72	73.5	71.1	69.7	9.9	93.9	0.2	7.3	20.0	19.6
2	35	981-73	72.2	69.4	68.0	11.0	93.4	0.3	10.3	20.2	19.4
2	36	981-74	70.8	64.7	63.4	11.6	93.7	0.2	7.8	20.6	20.1
2	37	981-75	73.3	66.3	64.9	9.2	93.8	0.2	8.5	19.5	20.2
2	38	981-76	74.1	68.5	67.1	8.8	93.9	0.2	9.2	19.5	19.7
2	39	981-77	74.7	70.1	68.6	8.5	94.1	0.2	8.9	19.8	19.7
2	40	Sunstate	77.6	78.4	76.8	11.8	92.5	0.5	8.5	19.9	20.4
2	41	Tincurrin	70.2	65.7	64.3	8.8	94.0	0.1	6.7	19.7	20.5
2	42	Tatiara	67.9	67.9	66.5	10.8	93.6	0.2	9.0	19.6	20.0
2	43	Bowie	73.0	70.9	69.4	10.9	93.5	0.2	9.3	19.5	19.6
2	44	Standard	75.5	70.1	68.3	10.7	93.9	0.3	7.8	19.7	19.7

9. Appendix (IV)

Junior Mill - Familiarisation

	Batch 1 - Milled 15/12/98			Batch 2 - Milled 16/12/98			Batch 3 - Milled 17/12/98		
Sample No.	Flour (g)	Mill (°C)	Room (°C)	Flour (g)	Mill (°C)	Room (°C)	Flour (g)	Mill (°C)	Room (°C)
1	63.36	19.6	20.4	62.66	19.1	20.6	64.14	19.3	20.4
2	62.19	19.9	19.7	62.70	19.4	20.4	63.44	19.0	20.0
3	61.76	20.6	20.3	63.27	19.7	20.1	62.81	19.5	19.5
4	62.38	20.8	20.9	62.88	20.1	20.2	62.36	19.8	19.2
5	60.40	19.9	20.2	62.96	20.5	20.3	61.67	20.5	19.6
6	61.80	19.6	19.6	62.68	20.5	20.1	62.06	20.8	20.2
7	61.06	19.5	19.1	62.62	20.8	20.5	61.43	20.7	20.5
8	61.48	19.8	19.9	61.71	20.9	20.6	61.98	20.1	20.1
9	60.83	20.0	20.6	62.09	20.3	20.8	60.16	20.1	19.8
10	60.94	20.1	20.8	63.68	19.0	21.2	60.90	20.2	19.6
11	60.76	19.9	20.5	63.35	19.5	20.5	60.26	20.2	19.4
12	61.25	19.8	19.9	62.92	19.1	20.0	60.28	20.1	19.0
13	60.31	19.7	19.3	63.04	19.3	19.8	60.71	20.4	19.5
14	61.11	19.5	19.0	62.71	19.4	19.7	60.20	20.4	20.3
15	60.79	19.7	19.6	61.78	19.6	19.6	60.74	19.8	20.6
16	61.11	19.3	20.1	61.70	19.7	19.6	60.00	19.7	20.3
17	61.09	19.3	19.5	62.44	19.9	19.5	59.54	19.7	20.1
18	60.89	19.5	19.6	62.01	20.0	19.5	59.54	19.7	19.8
19	61.12	19.7	20.2	62.22	20.0	19.5	59.02	19.8	19.6
20	61.25	19.5	19.7	61.75	20.0	19.5	60.63	20.1	20.1
21	60.75	19.5	19.4	61.62	20.1	19.5	59.40	20.2	20.7
22	61.43	19.7	19.6	62.11	20.2	19.5	60.53	19.9	20.9
23	60.87	19.8	20.2	61.92	20.3	19.5	59.55	19.9	20.5
24	60.65	19.7	19.8	61.93	20.3	19.5	59.71	19.9	20.2
25	63.62	19.5	19.5	61.44	20.3	19.5	60.13	19.9	19.9
26	62.04	19.6	19.7	61.74	20.3	19.6	62.77	19.3	20.5
27	62.79	19.9	19.9	61.61	20.2	19.6	62.34	19.9	19.9
28	62.02	19.9	20.5	61.82	20.1	19.6	62.28	19.6	19.7
29	60.32	19.8	20.1	61.70	20.2	19.6	61.39	19.8	19.5
30	61.77	19.7	19.7	61.29	20.2	19.6	62.10	20.1	19.4
31	62.07	19.7	19.4	61.40	20.2	19.5	62.22	20.2	19.6
32	62.16	19.9	19.1	62.17	20.2	19.5	62.50	20.4	20.1
33	61.87	20.4	19.8	61.91	20.1	19.5	61.83	20.1	20.0
34	61.77	20.1	20.8	61.62	19.9	19.7	61.80	20.1	19.8
35	62.34	19.8	21.0	62.34	19.8	19.7	62.37	20.1	19.8
36	62.24	19.6	20.6	62.29	20.0	19.8	61.92	20.1	19.7
37	61.26	19.7	20.4	62.33	20.1	19.8	62.05	20.1	19.7
38	61.80	19.6	20.1	62.32	20.0	19.8	61.94	20.0	19.5
39	61.41	19.6	19.9	61.57	20.0	19.8	62.66	19.9	20.0
40	61.17	19.6	19.7	61.54	20.1	19.8	62.12	20.2	20.5
41	61.50	19.7	19.6	61.84	20.1	19.8	61.85	19.6	20.5
42	61.49	20.1	19.4	61.48	20.1	19.8	62.22	19.2	20.4
43	61.64	20.2	19.3	61.47	20.5	20.4	61.25	19.5	20.2
44	61.58	20.4	19.7	61.48	19.7	20.6	60.97	19.9	20.0
45	61.33	20.8	20.7	61.10	19.2	20.5	61.41	20.3	19.8
46	61.21	20.2	20.9	61.29	19.2	20.5	61.61	20.3	19.8
47	60.81	19.7	20.9	61.71	19.4	20.5	61.56	20.4	19.7
48	61.30	19.4	20.6	61.80	19.5	20.4	61.68	20.5	19.6
49	61.43	19.4	20.4	61.41	19.4	20.4	61.65	20.5	19.5
50	61.97	19.4	20.1	61.81	19.4	20.3	61.63	20.6	19.4
Mean	**61.49**	**19.80**	**19.99**	**62.06**	**19.92**	**19.95**	**61.39**	**20.01**	**19.93**
Std Dev	**0.70**	**0.35**	**0.54**	**0.60**	**0.45**	**0.45**	**1.12**	**0.39**	**0.42**

9. Appendix (V)

Senior Milling – Noodle Benchmarking

Site	Cultivar	Initial Sample Size (g)	Mean Moisture (%)	Flour Weight (g)	Bran Weight (g)	Pollard Weight (g)	Flour Composition (%)	Bran Composition (%)	Pollard Composition (%)
Moree	Banks	3000	11.1	2346	682	84	72.22	20.99	2.60
	Sunstate	3000	11.1	2324	666	105	71.90	20.60	3.23
	Sunco	3000	10.6	2364	669	83	75.87	21.48	2.66
Gilgandra	Banks	3000	10.8	2229	732	108	72.63	23.84	3.53
	Sunstate	3000	10.6	2344	647	164	74.27	20.52	5.21
	Sunco	3000	10.5	2228	784	107	71.42	25.14	3.44
North Star	Banks	3000	11.1	2371	627	106	76.37	20.20	3.43
	Sunstate	3000	11.1	2347	633	108	76.00	20.50	3.50
	Sunco	3000	10.7	2362	642	87	76.41	20.76	2.83

9. APPENDIX (VI)

DOUGH PROPERTIES - AYT981

Cultivar ID	EOWA (%)	Formation (secs)	Peak Height (MU)	Stability (secs)	Breakdown (MU)
981-1	57.43	60	6.0	40	0.2
981-2	58.14	75	5.3	75	0.3
981-3	57.24	75	5.4	95	0.3
981-4	55.81	65	4.3	95	0.1
981-5	58.69	75	6.0	100	0.4
981-6	58.21	65	5.2	95	0.2
981-7	57.67	90	5.8	75	0.2
981-8	57.75	85	5.7	80	0.1
981-9	58.71	75	5.8	70	0.1
981-10	58.09	95	5.8	60	0.2
981-11	60.07	75	6.4	75	0.2
981-12	58.83	45	5.4	90	0.2
981-13	59.22	90	4.8	50	0.1
981-14	59.23	45	5.0	80	0.1
981-15	58.65	70	4.5	95	0.1
981-16	58.57	80	5.6	65	0.2
981-17	60.81	65	6.3	70	0.2
981-18	57.15	60	5.8	65	0.2
981-19	59.68	75	6.3	55	0.2
981-20	58.84	75	6.8	45	0.1
981-21	60.31	65	6.5	50	0.2
981-22	59.71	75	6.7	90	0.2
981-23	57.94	85	5.9	95	0.3
981-24	57.37	50	5.7	60	0.1
981-25	58.72	65	6.7	50	0.2
981-26	56.88	40	4.8	90	0.1
981-27	56.16	50	5.4	65	0.1
981-28	58.57	60	6.3	55	0.1
981-29	56.43	50	5.8	45	0.1
981-30	56.05	50	5.4	60	0.1
981-31	56.64	50	5.0	95	0.1
981-32	57.81	60	5.3	85	0.1
981-33	56.14	35	5.1	80	0.2
981-34	56.85	65	5.7	30	0.2
981-35	57.01	65	5.3	40	0.1
981-36	60.01	120	5.2	195	0.3
981-37	60.06	135	5.5	150	0.5
981-38	59.62	85	5.3	100	0.2
981-39	59.85	85	5.6	55	0.3
981-40	61.75	95	7.2	95	0.6
981-41	60.06	70	5.3	90	0.2
981-42	59.17	75	5.5	75	0.3
981-43	61.20	90	6.4	170	0.5
981-44	56.38	60	4.8	135	0.2
981-45	61.93	60	5.8	105	0.2

9. APPENDIX (VII)

DOUGH PROPERTIES - AYT981

Cultivar ID	EOWA (%)	Formation (secs)	Peak Height (MU)	Stability (secs)	Breakdown (MU)
981-46	60.03	75	5.9	130	0.4
981-47	56.13	40	5.7	40	0.1
981-48	58.23	60	5.8	120	0.2
981-49	58.84	60	5.1	65	0.1
981-50	60.13	75	5.5	105	0.2
981-51	59.20	70	5.4	85	0.2
981-52	58.30	90	5.8	80	0.3
981-53	57.67	60	5.5	50	0.1
981-54	60.91	75	6.6	50	0.1
981-55	59.74	45	5.5	90	0.1
981-56	59.25	50	6.0	70	0.2
981-57	60.13	65	5.9	75	0.2
981-58	57.93	60	5.0	45	0.1
981-59	59.41	60	5.6	65	0.2
981-60	59.46	55	5.2	70	0.1
981-61	60.58	60	6.0	90	0.2
981-62	58.86	55	5.2	85	0.1
981-63	59.05	60	5.5	80	0.1
981-64	58.35	65	5.2	80	0.1
981-65	58.41	60	5.1	75	0.1
981-66	59.32	75	5.5	120	0.1
981-67	59.26	60	5.3	75	0.2
981-68	57.15	45	5.0	110	0.1
981-69	59.28	55	5.2	130	0.2
981-70	57.93	45	5.0	110	0.1
981-71	59.05	60	5.3	110	0.1
981-72	58.45	45	4.8	115	0.1
981-73	60.06	60	6.2	55	0.1
981-74	60.94	55	6.5	50	0.2
981-75	57.46	40	5.4	55	0.1
981-76	56.79	45	5.7	45	0.1
981-77	56.29	60	4.5	55	0.1
Sunstate	61.35	135	6.2	105	0.3
Tincurrin	56.74	50	4.2	110	0.1
Tatiara	59.77	65	5.9	80	0.1
Bowie	59.91	85	6.5	55	0.1
Standard	58.51	80	5.0	120	0.2
Standard	59.14	70	6.0	100	0.2
Standard	58.65	65	5.6	110	0.2
Standard	59.59	95	5.3	115	0.1
Standard	58.86	80	5.2	100	0.2
Standard	59.62	95	5.3	120	0.2

9. Appendix (VIII)

Site Grain Yields – AYT981

	Narrabri			North Star		Moree		Forbes	
Cultivar	1998	1997	1996	1998	1997	1997	1996	1998	1997
981-1	2.76	3.93	4.72	1.44	1.83	2.42	3.26	3.77	1.12
981-2	3.10	3.75	3.68	1.49	2.44	2.10	2.92	4.02	1.50
981-3	3.38	3.79	3.36	0.93	2.40	2.11	2.59	5.00	1.38
981-4	3.23	3.96	3.50	0.60	2.22	2.12	2.48	4.46	1.05
981-5	3.47	3.86	4.38	1.21	2.91	1.92	3.64	5.33	1.29
981-6	3.15	3.71	3.77	1.00	2.87	2.40	3.50	4.51	1.10
981-7	3.12	4.03	3.52	1.57	2.37	1.87	2.78	4.43	1.11
981-8	1.99	3.54	3.65	1.07	1.91	1.95	3.31	3.53	1.31
981-9	3.19	3.25	4.03	0.78	2.39	1.52	3.45	3.15	1.22
981-10	3.59	3.35	3.37	0.57	2.46	1.62	3.45	2.94	1.24
981-11	2.90	3.73	3.56	1.17	2.45	1.79	4.05	3.93	1.34
981-12	2.88	3.61	3.94	1.53	1.96	1.58	3.85	3.20	1.18
981-13	3.04	3.73	3.70	1.31	2.21	1.75	3.97	5.05	1.34
981-14	3.08	3.98	3.42	1.19	1.68	1.64	3.21	4.24	1.31
981-15	2.58	4.58	3.98	0.79	1.69	1.59	3.28	4.39	1.30
981-16	3.63	4.09	3.41	1.53	2.69	1.73	3.59	4.50	1.27
981-17	2.73	2.95	3.82	0.76	1.96	1.53	2.81	3.81	1.16
981-18	2.88	3.41	3.22	1.44	2.29	1.98	2.51	4.10	1.36
981-19	3.73	3.16	2.26	0.58	2.35	1.11	3.54	3.31	1.24
981-20	2.78	3.84	3.70	1.26	2.37	2.09	2.65	4.12	1.52
981-21	3.06	3.97	4.22	2.05	2.11	2.18	2.78	4.42	1.30
981-22	2.58	3.88	2.92	1.04	2.09	2.03	2.68	4.19	1.36
981-23	3.18	3.51	2.81	0.70	2.16	2.38	2.64	3.43	1.38
981-24	4.02	3.37	2.07	1.27	2.16	1.41	2.81	3.62	1.67
981-25	2.64	2.97	3.58	0.59	2.23	1.08	3.61	3.25	1.40
981-26	3.31	3.62	3.06	1.22	2.21	1.58	4.25	5.15	1.64
981-27	3.36	3.55	2.80	1.23	2.91	0.81	2.48	4.88	1.30
981-28	2.99	3.19	3.09	0.65	2.66	1.05	3.09	3.97	1.38
981-29	3.20	3.69	2.41	1.27	2.35	0.94	2.55	3.56	1.47
981-30	2.86	3.32	2.85	0.84	2.79	0.99	3.86	4.11	1.68
981-31	3.51	3.24	2.45	0.66	2.11	1.47	2.98	2.92	1.48
981-32	3.63	3.45	2.65	0.82	2.65	1.33	2.31	4.22	1.42
981-33	2.81	3.50	2.76	0.81	1.74	0.75	3.09	4.46	1.29
981-34	2.73	3.63	3.39	1.12	2.24	1.29	2.58	4.25	1.45
981-35	3.85	3.14	3.92	1.07	2.60	1.46	2.55	4.39	1.81
Tincurrin	2.90	3.79	2.39	0.71	2.04	0.97	2.36	4.62	1.39
Tatiara	2.45	3.34	2.51	0.94	1.88	1.59	1.60	4.06	1.16
Sunstate	2.99	2.81	1.60	2.14	2.51	1.77	1.35	4.22	1.28
Mean	**3.09**	**3.58**	**3.27**	**1.09**	**2.29**	**1.63**	**3.01**	**4.09**	**1.35**
Std Dev.	0.42	0.36	0.68	0.39	0.33	0.45	0.64	0.61	0.17