QUALITY WHEAT
CRC PROJECT REPORT

The Effect of Wheat Types, Flour Quality Attributes and Processing Conditions on the Quality of Extruded Snack Foods

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Food Science Australia

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Executive Summary

The Quality Wheat CRC and Australian Wheat Board has a focus to promote hard wheat in a wide range of end products. In addition, Goodman Fielder is interested in the expansion of hard wheat utilisation for domestic use and export by developing value added products. The main aim of this project was to evaluate the flour quality attributes and processing behaviour of low protein hard wheat in the production of extruded snacks in comparison to low protein soft wheat.

The effect of variety and form of wheat on the extrusion properties have been extensively reviewed and presented (**Appendix 4**). From this review it was concluded that the importance of wheat characteristics on product quality is believed to be, (in descending order) protein content, wheat variety (hard or soft), particle size, fat (added), geographic location, amylose content, storage conditions and type of extruder. In addition, the effect of grain hardness, protein, fat and amylose content on the product characteristics were discussed extensively.

A preliminary study based on a comparison of the extrusion behaviour of wheat types with extreme ranges of softness and hardness was carried out. The selected wheats included a soft wheat (Debranning soft) and a hard wheat with two levels of milling (Bakers grist, low grind and Bakers grist, high grind).

This preliminary study demonstrated that hard wheat consumed more energy to process for small increases in expansion. The product quality was significantly affected by the processing conditions and the effect of the particle size and hardness were small.

In the next trial, a low protein hard wheat was compared to a high protein hard wheat and a low protein soft wheat. Extrusion conditions were selected to distinguish between the processing behaviour and product qualities of the three wheat types. The results obtained indicated that there are no advantages to be gained by using a high protein hard wheat in extrusion food applications, where the desirable characteristics for a raw material are the production of good expansion and texture with the lowest energy input. In general the protein in wheat tends to reduce expansion. The low protein hard wheat showed the greatest expansion with the lowest energy input.

Two strategies were developed to further investigate the promising characteristics of the low protein hard wheat for extrusion of snack products. The first approach was to repeat the previous comparative trial under adiabatic conditions, using processing settings as recommended by an industry user. Sensory evaluation on the three expanded products showed that low protein hard wheat had a less acceptable flavour and texture than low protein soft wheat. Based on this finding, the second approach was to optimise the extruder conditions for product attributes from low protein hard wheat. A cheese and bacon flavoured snack was produced from the low protein soft and hard wheats, using the optimised conditions. Sensory evaluations showed that there was no significant difference (5% level) between the quality of the product made with low protein hard wheat compared to low protein soft wheat.

This project has demonstrated that low protein hard wheat can replace low protein soft wheat in the production of extruded snack foods. With the snack food industry adopting greater use of twin screw extruders this work has particular pertinence. Varied formulations and product attributes offer greater opportunities for wheat use in extrusion.

1. Introduction

Extruded snack foods are becoming an important end-use for wheat and they provide a high level of value addition. Markets in Asia such as South Korea have indicated their interest in using Australian wheat for the production of extruded foods. In addition, Goodman Fielder is interested in this technology for the production of domestic and export commodities. Very little research has been attempted on the use of Australian wheat for extruded snack food products. Pre-competitive research is required to pilot the opportunities for using Australian wheat to service this market requirement.

Australia produced 15 million tonnes of wheat annually for the last ten years and 80 to 84% of the total production is exported. Australian wheat is used for a wide range of applications both domestically and in export markets throughout the world. The vast majority of the crop is now leading towards hard wheat. It is therefore important to understand the flour quality attributes of hard wheat to suit with the market requirements for the production of desirable characteristics of wheat based products.

In this wheat CRC project the focus has been directed primarily towards evaluating wheat types for their use in extruded food products. More specifically, the goal of this work has been to determine if low protein hard wheat could offer advantages compared to the traditional use of soft wheat types for extrusion. A positive finding could create a valuable wheat market for low protein hard wheat. Establishment of key wheat and flour quality attributes will assist the marketing of Australian wheat and domestic manufacturing in the high value extruded snack food market.

2. Project aims

When the project commenced it had the following objectives:

- To determine the contribution of flour quality attributes in the extrusion of wheat based snack foods and specifically to evaluate low protein hard wheat.
- To develop strategies to use low protein hard wheat for the production of extruded products with particular emphasis on snack foods.
- To set breeding objectives for the development of wheats of specific quality and to assess current advanced breeding materials.

However, as the project progressed, its scope was changed to achieve the following objective:

- To optimise the operating conditions of a pilot scale twin screw extruder to produce an expanded snack product of acceptable sensory properties using low protein hard wheat.

3. Materials and methods

3.1 *Raw materials*

3.1.1 Flours

A total of seven flours from five wheat types and 1 maize type were provided by the Quality Wheat CRC commercial partner, Goodman Fielder. The details of wheat and maize flour types were as follows:

Soft wheat (Debranning soft)
Hard wheat (Bakers grist, low grind)
Hard wheat (Bakers grist, high grind)
High protein hard wheat (HYPRO Hard)
Low protein hard wheat (LOWPRO Hard)
Low protein soft wheat (LOWPRO Soft)
Maize flour (Polenta)

Hard wheat was obtained from northern and southern NSW, soft wheat from southern NSW and maize from southern NSW. Wheat was milled at Goodman Fielder Mill, Summer Hill and maize at Waratah Mill, Dulwich Hill.

3.1.2 Characterisation of flours

Characterisation of milled flours was performed at R and D laboratory of the Milling and Baking Section, Goodman Fielder. The following analytical tests were performed in duplicate on all six commercial wheat flours.

Moisture (AACC Method 44-15A)
Protein content (Kjeldhal, N x 5.7), (AACC 46-12)
Ash content (AACC 08-01)
Starch damage (AACC 76-30A)
Total Starch (AACC 76-12)
Wheat hardness (Near Infrared Reflectance)
Colour grade (Henry Simon Series IV)
Reducing sugars (BRI 12, HPLC)
Falling Number (AACC 56-81B)
Rapid ViscoAnalyser (Hohn Profile, 4g)
Water absorption (RACI Official testing Methods)
Development time (")
Extensibility (")
Viscograph (")
Particle size % $<40\mu m$ (Malvern laser diffraction method)

The results are listed in **Appendix 1.** On maize flour selected analyses (moisture, protein, ash, fat, sieving test and particle size measurement) were performed (see **Appendix 2** for results).

3.2 Extrusion

3.2.1 Extrusion processing

A twin screw extruder (model MPF 40, APV Baker, Peterborough PE3-6TA, England) with 40mm screw diameter and length to diameter ratio (25:1) was used (**Figure 1, Appendix 3**). The barrel has nine temperature control zones (**Figure 1**).

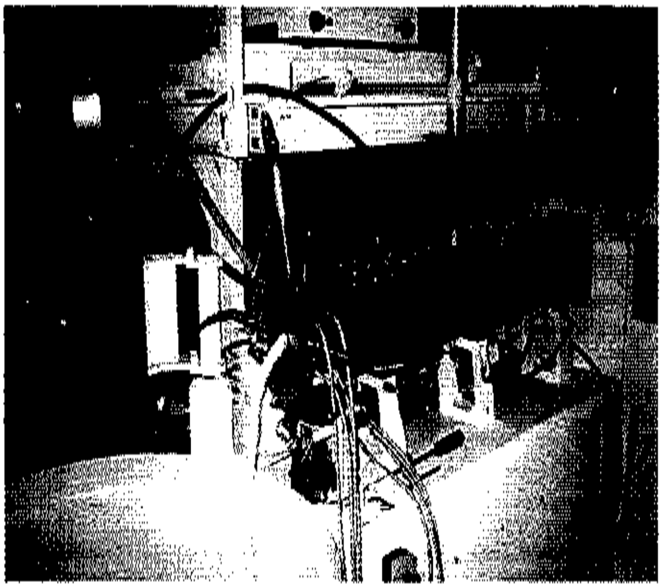


Figure 1: A wheat product extruded from the twin screw extruder (Model MPF 40, APV Baker), Food Science Australia.

The screw configuration and die specification used to generate low shear in a preliminary study of 3 wheat flours, was: *3*30° Forward Paddle (FP), 160 mm Feed Screw (FS), 7*30° FP, 80 mm FS, 7*30° FP, 80 mm FS, 7*30° FP, 110mm FS, 7*30° FP, 60mm FS, 7*30° FP, 4*60° Reverse Paddle (RP), 80 mm Single Lead (SL), die (single, 4mm diameter).* Length to diameter ratio was 25.

Raw materials were fed into feed port 1, using a gravimetric feeder (Ktron Soder AG CH-5702, Niederlenz) and water was injected into zone 1 with a volumetric pump (Brook Crompton, Huddersfield, England).

The screw configuration used to generate medium to high shear in the trial of 3 wheat flours, was: *200 mm FS, 7*30° FP, 160 mm Lead Screw (LS), 2*90° Paddle (P), 40 mm LS, 2*90° P, 4*30° RP, 40 mm LS, die (single, 4mm diameter).* Length to diameter ratio was 15.

The screw configuration used to generate high shear for the trial of adiabatic condition of 3 wheat flours, was: *200 mm FS, 8*30° FP, 200 mm LS, 4*90° P, 7*30° RP, 40 mm LS, die (single, 4mm diameter).* Length to diameter ratio was 15. Raw materials were fed through zone 4 and water was injected into zone 5 in the shorter screw configuration trials.

Extrusion parameters were monitored by a real time, PC-based process control system using CITECT software. The logged-on parameters included feeder and water injector rates, temperature (set, process and melt), screw speed, motor torque and Specific Mechanical Energy (SME), die temperature and pressure, cutter speed and process time. The logged data were used to measure the variations in the independent variables and to assess the mean values for these variables. Feed rates of 25 or 30 kg h^{-1} were used throughout the trial.

3.2.2 Pre-extrusion processing

All flours were sieved through a vibrating screen (2mm) prior to extrusion. The moisture of sieved flour was determined by a moisture analyzer (Sartorius, MA 30, Gorttingen, Germany). The initial moisture of flour was used to calculate the water flow into the barrel to achieve the desired barrel moisture content.

3.2.3 Extrudate collection

The steady state samples were collected and hot air dried at 49-52°C for 16h. Dried samples had a 5-6% moisture content and were kept in sealed bags prior to analysis.

3.2.4 Extrudate analysis - general properties

Specific volume (SV) was measured by displacement of glass beads (1mm) according to Guy and Roberts, 1984.

The radial expansion index (REI) was measured as the ratio of the cross-sections of extrudate to that of the die.

An index of longitudinal expansion (LE) was calculated from SV and diameter using the following equation, based on the assumption that all extrudates are cylindrical in shape.

$$LE = SV / \text{Area of extrudate}$$

The hardness (HD) and crispness (CP) of the oven dried extrudates were determined by a pin penetration test (diameter 1mm), using a model TAXT2 Texture Analyser (Stable Micro Systems, Haslemere, UK). The test speed was 0.5 mm/s and the load cell used was 25 kg. Data was collected and analysed using Texture Expert (version 1.11) for Windows software. Pasting properties of extrudates were measured with a Rapid Viscoanalyser (Model 4, Newport Scientific).

3.2.5 Extrudate analysis - sensory evaluation

The expert sensory panel evaluations were carried out on the whole wheat expanded samples at the R and D Centre, Uncle Tobys, Rutherglen, Victoria.

The flavour coated low protein hard and soft wheat expanded products were evaluated at the computerised sensory facility of Food Science Australia, Werribee. A triangle test was used to determine sensory differences between the products made from two wheats.

Complete details of this testing are provided in **Appendices 7, 8 and 9**.

4. Results and discussion

4.1 Review of the effect of wheat type and form of cereals on the properties of the extrudate

The effect of variety on the extrusion properties of wheat has been reviewed and is presented in detail in **Appendix 4**. From this review it was concluded that the physical and chemical properties of cereal extrudates, are more affected by the difference in variety, geographic location, particle size and storage conditions.

The main variations in wheat are hardness/softness of grain, protein, amylose and fat content, and geographic location of the crop. If the protein content is similar, hard wheat creates a more severe processing environment, causing higher heat and shear inputs, than soft wheat. It consequently tends to expand more producing large cells. Hard wheat with high protein requires even more energy and produces rough cell walls. Expansion generally increases with increasing amylose content. The presence of fat in cereal normally reduces the power requirement and product expansion.

Particle size is also one of the important factors in wheat expanded products. The optimum particle size to produce a product of general acceptance is between 120-150μm.

The effect of storage on extrudate property is unaffected if the storage temperature is -11°C. Prolonged storage in ambient conditions tends to reduce expansion and produce slimmer extrudates with a higher pore density. These differences in physical and chemical properties of extrudates are more pronounced if severe extruder conditions, such as high shear screw configuration, low moisture and high screw speed are used.

From literature cited, the importance of wheat characteristics on snack quality is (in descending order) protein content, wheat texture (hard or soft), milled size, fat (added), geographic location, amylose content, storage conditions and type of extruder.

4.2 Preliminary study on the effect of flour type on the extrusion characteristics of wheat flours

A preliminary trial was undertaken to gauge the difference in extrusion processing characteristics between flours obtained from wheats representing extreme values for hardness and softness in commercial Australian samples. The wheats selected were a soft wheat (Debranning soft) and a hard wheat (Bakers grist) with two different millings (low and high grind, **Appendix 5**).

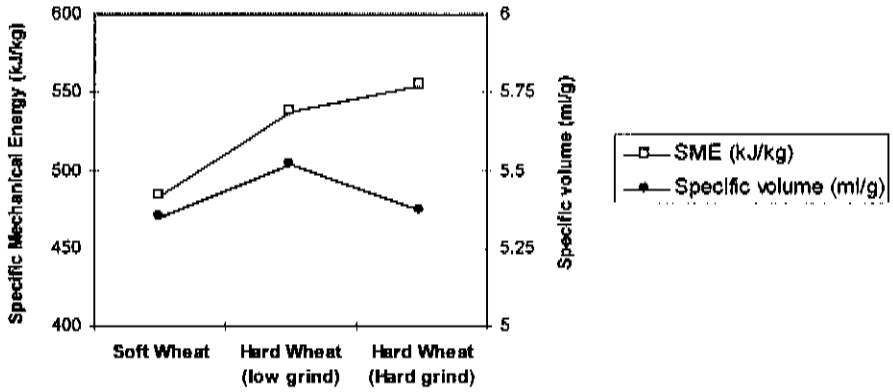


Figure 2: Specific Mechanical Energy (SME) and overall expansion (SV) of soft and hard wheat flour, all processed under same conditions (barrel moisture 22%, temperature at the last zone, adjacent to die 160°C and screw speed 400 rpm).

Whole wheat flours were extruded using a long barrel arrangement (24.75D) with a low shear screw configuration. Processing conditions were chosen to encompass the normal operating conditions used for wheat-based foods. The extruder responses were recorded and characteristics of the product from the three wheats were measured. These measurements were the energy required to extrude the wheats, determined as specific mechanical energy (SME), and extrudate characteristics such as, bulk density, specific volume and radial expansion (**Appendix 5**). In general the hard wheat took more energy to process for small increases in expansion.

Differences arising both from the level of grind and hardness were of small magnitude, and considerably influenced by the processing conditions such as barrel moisture, temperature at the last zone and screw speed (**Table 1**). The results from **Table 1** showed that generally wheat type had a greater effect on expansion than the milling level. The magnitude of differences in expansion was greatest for differences in extruder conditions.

The results from this preliminary study indicated that differences in the extrusion behaviour between a soft and a hard wheat were small but observable and consistent with the previously reported observations.

Table 1: Extruder conditions and physical properties of three wheat expanded products

	Extruder Conditions			Wheat Flour extrudate		
Physical Property	Moist (%)	Temp (°C)	Screw speed (RPM)	Soft Wheat (Debranning Soft)	Hard Wheat (Low Grind)	Hard Wheat (Hard Grind)
	22	150	275	415.8	480.5	462.0
SME	22	160	400	483.8	537.6	537.6
(kJ/kg)	17	162	275	554.4	563.6	554.4
	17	170	400	591.4	618.2	604.8
Specific	22	150	275	4.81	4.90	4.60
Volume	22	160	400	5.35	5.52	5.37
(ml/g)	17	162	275	10.86	12.60	11.90
	17	170	400	14.81	17.23	17.08
Radial	22	150	275	3.59	3.49	3.45
expansion	22	160	400	2.78	2.74	2.59
index	17	162	275	4.16	4.37	4.31
	17	170	400	4.28	4.32	4.30

4.3 An evaluation of low protein hard wheat flour. A comparison with conventional soft and hard wheat flours

A low protein hard wheat flour (LOWPRO HARD) was compared with two commercial flours chosen to represent the extreme range for grain hardness, i.e. a low protein soft wheat flour (LOWPRO SOFT) and a high protein hard wheat flour (HYPRO HARD). The complete flour analysis on the selected wheat flours was shown in **Appendix 6**. A comparison of some of the properties of these three flours is given in **Table 2.**

Table 2: Properties of wheats

Wheat variety	Protein (N x 5.7) (%)	Falling No. (sec)	Water Absorption (%)	Particle size < 40μm (%)	RVA, Final viscosity (RVU)
LOWPRO Soft	7.9	363	59.6	43	427
LOWPRO Hard	8.6	514	58.9	33	419
HYPRO Hard	12.9	660	65.9	22	344

The hard wheat produced more damaged starch during milling which can be seen from the higher water absorption value.

A short barrel configuration (15D) was used with a medium to high shear screw arrangement, which produced a melt in the final barrel zone adjacent to the die section. Barrel temperature settings were kept the same for all trials, to investigate frictional differences between the wheat flours that could be observed from differences in temperature of the barrel melts. Barrel moisture (four levels, 16%, 18%, 20% and 22%) and screw speed (two levels 275 and 350 rpm) were the processing conditions varied to differentiate between the extrusion behaviour of the wheats. The responses measured were die pressure, melt temperatures, torque, specific mechanical energy, specific volume, radial and longitudinal expansion index, pasting viscosities (RVA), pore dimensions and texture.

HYPRO hard wheat required the highest energy under all processing conditions and LOWPRO hard wheat generally required least energy. Ranking of the differences between the wheats was affected by both processing variables. Under the lowest barrel moisture conditions, the LOWPRO hard wheat showed the greatest expansion with the lowest energy input (**Table 3**). The expansion behaviour of the three wheat extrudates is shown in **Figure 4**.

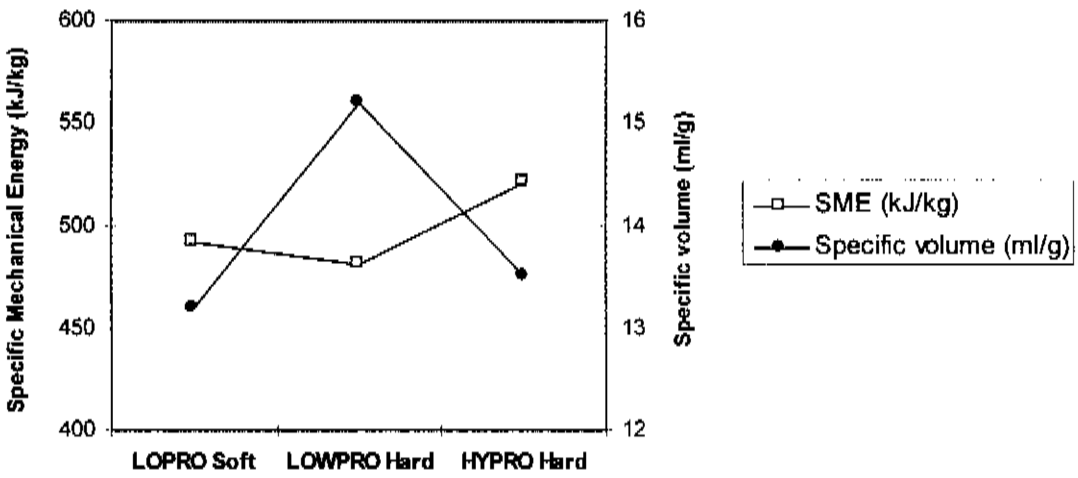
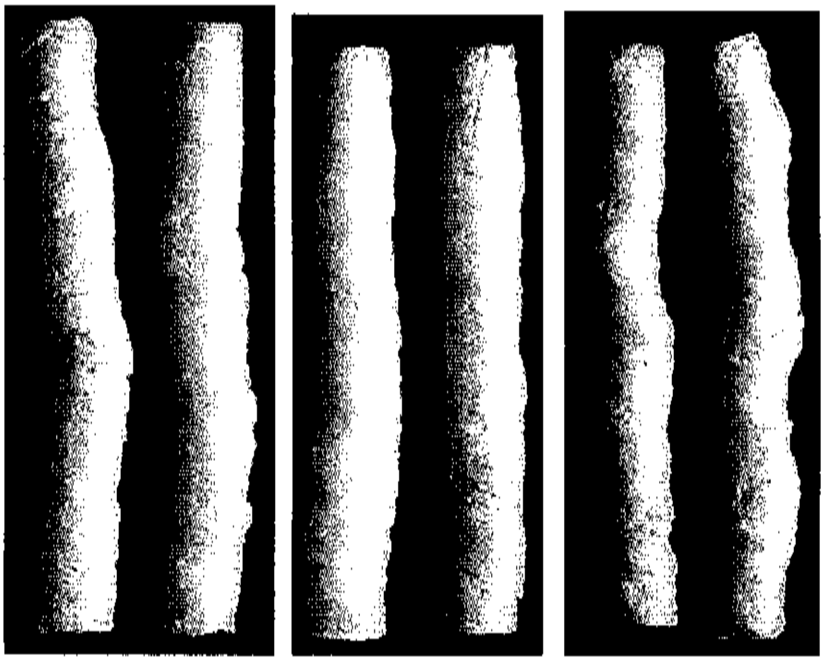


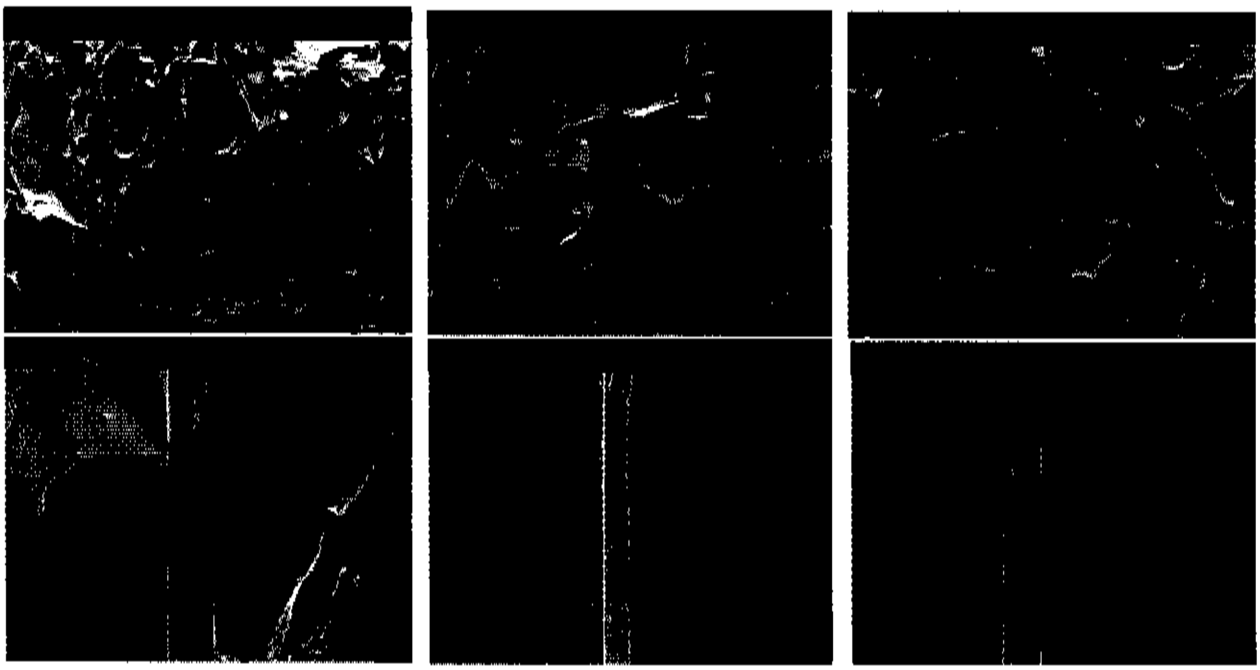
Figure 3: **Energy required to process (SME) and overall expansion (SV) of soft and hard wheats, all processed under same conditions (barrel moisture 16%, melt temperature at the last zone, adjacent to die 180°C and screw speed 350 rpm).**

The cell structure and thickness was examined by scanning electron microscopy to determine the expansion behaviour of the three wheat types (**Figure 5**). LOWPRO hard wheat expanded into a uniform honeycomb cell structure with thinnest cell wall.



LOWPRO Soft LOWPRO Hard HYPRO Hard

Figure 4: **The expansion behaviour of the three wheat extrudates, all processed under the same conditions (as for Fig 3).**



LOWPRO Soft LOWPRO Hard HYPRO Hard

Figure 5: **Scanning electron micrographs of the three wheat extrudates, all processed under the same conditions (as for Fig 3)**

Table 3: Extruder conditions and physical properties of three wheat expanded products

	Extruder Conditions			Wheat Flour extrudate		
Physical Property	Moist (%)	Temp (°C)	Screw speed (RPM)	LOWPRO Soft	LOWPRO Hard	HYPRO Hard
SME	20	147	350	435	424	483
(kJ/kg)	18	154	350	472	454	505
	16	158	350	492	481	521
Specific	20	145	350	5.5	4.7	6.1
Volume	18	151	350	9.7	9.1	11.7
(ml/g)	16	157	350	13.2	15.2	13.5
	20	144	350	5.3	3.3	6.7
Hardness	18	151	350	4.5	2.6	5.0
(N/mm)	16	157	350	2.3	2.5	2.9

The magnitude of differences in hardness (texture) of the three wheats was small and unlikely to be significant (**Table 3**). Although the same temperature was set for all wheat products, HYPRO hard wheat generated more heat from friction of hard grains (**Appendix 6**). At the lowest barrel moisture, LOWPRO hard generated a similar barrel temperature to HYPRO hard. The higher temperature of starch melts from HYPRO and LOWPRO hard wheat may produce more aroma or flavour in these products. In this respect, it could be expected that a significant difference in sensory attributes between soft and hard wheat products may occur.

Sensory testing was included in all subsequent trials. The results from this trial demonstrated that products obtained from LOWPRO hard wheat flour were superior to products from other wheats, although the magnitude of the differences was not large. Subsequent trials were required to test the commercial significance of these results.

4.4 A comparison of the extrusion behaviour of three wheat varieties under high shear and adiabatic conditions.

Further trials with the twin screw extruder were carried out to validate the previous observations under more typical commercial operating conditions. These conditions included the use of a high shear screw configuration, a die of lower conductance value and extrusion under adiabatic conditions. Using these conditions resulted in slightly greater differences in the product characteristics (**Appendix 7**). However, there were no significant differences in product characteristics between LOWPRO hard and LOWPRO soft wheat extruded at low moisture content. LOWPRO hard wheat again required the lowest amount of energy to produce expanded products (**Table 4**).

Table 4: **Extruder conditions and physical properties of three wheat expanded products**

	Extruder Conditions*			Physical properties		
Wheat flour Extrudate	Moisture (%)	Melt Temp (°C)	Screw speed (RPM)	SME (kJ/kg)	Specific volume (ml/g)	Hardness (N/mm)
LOWPRO	20	170	325	553	13.7	1.49
Soft	18	184	325	594	12.0	1.94
Wheat	16	191	325	591	9.1	2.86
LOWPRO	20	175	325	550	12.7	1.61
Hard	18	187	325	569	11.5	1.91
Wheat	16	192	325	590	9.2	3.17
HYPRO	20	180	325	574	15.6	1.33
Hard	18	193	325	598	15.6	1.86
Wheat	16	196	325	595	11.9	3.33

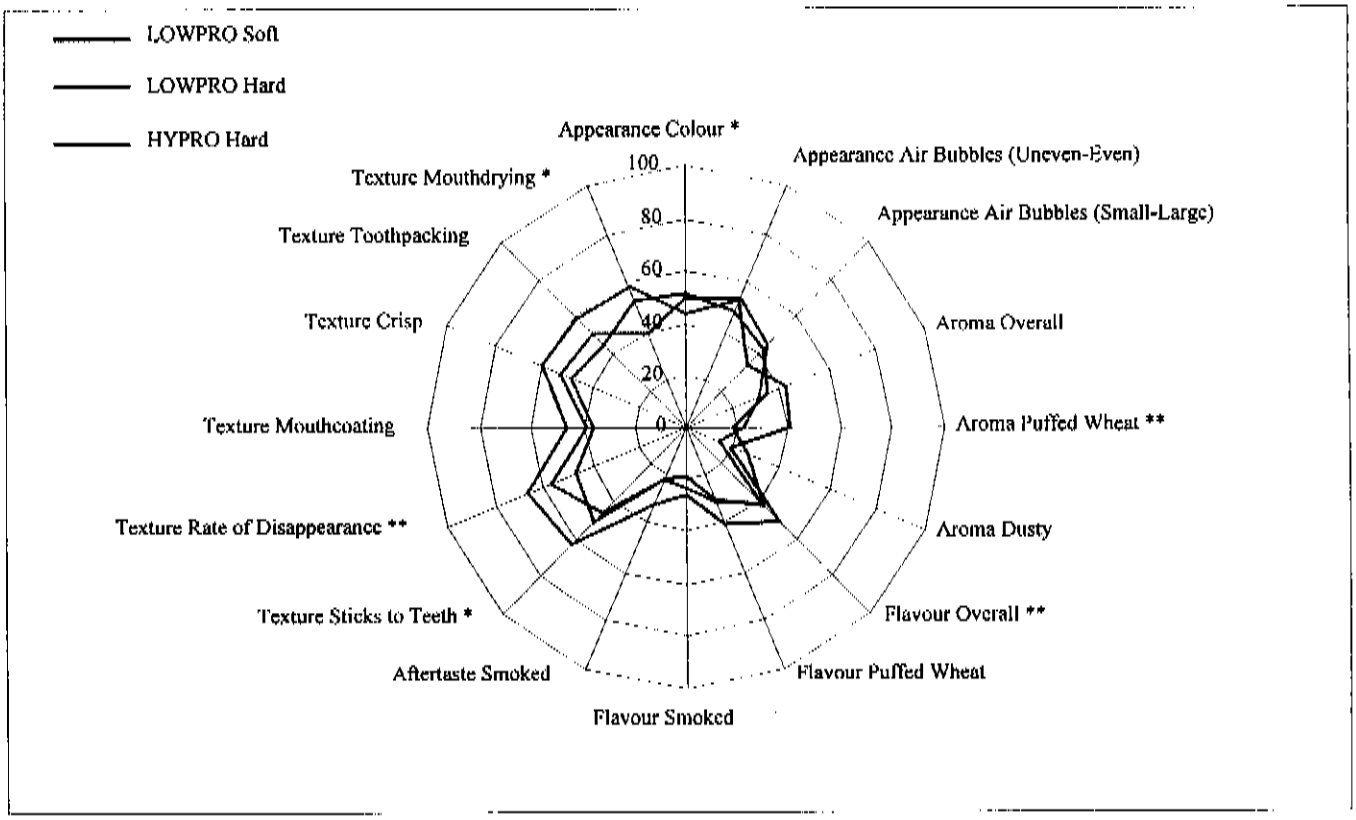
* 30 kg/h feed rate

Table 5: **Attributes and anchor points of the three wheat extrudates, all processed under the same conditions (barrel moisture 16%, melt temperature at the last zone, adjacent to die 150°C and screw speed 325 rpm)**

ATTRIBUTES		ANCHOR POINTS	
Appearance	Colour	White	Light Brown
	Air Bubbles	Uneven	Even
	Air Bubbles	Small	Large
Aroma	Overall	Weak	Strong
	Puffed Wheat	Weak	Strong
	Dusty	Weak	Strong
Flavour	Overall	Weak	Strong
	Puffed Wheat	Weak	Strong
	Smoked	Weak	Strong
	Aftertaste, Smoked	Weak	Strong
Texture	Sticks to Teeth	Not Much	Much
	Rate of Disappearance	Slow	Fast
	Mouth coating	Not Much	Much
	Crispness	Not Very	Very
	Tooth packing	Not Very	Very
	Mouth drying	Not Very	Very

The sensory attributes of the products were tested for their appearance, aroma, flavour and texture. Sixteen sensory attributes were evaluated and mean sensory scores were calculated. Attributes were scored on a line scale of 0-100 mm. The anchor points for each attribute are listed in **Table 5**.

The findings of the expert sensory panel evaluation on the three expanded products was that LOWPRO hard wheat had significantly stronger puffed wheat aroma and overall flavour, more tooth packing, faster rate of disappearance, more mouth-drying and more sticking to teeth than LOWPRO soft wheat (**Figure 6**). The HYPRO hard wheat variety also had a significantly stronger puffed wheat aroma, overall aroma and smoked flavour aftertaste compared to LOWPRO hard and soft wheats. The overall sensory results indicate that both hard wheats undergo more dextrinisation and generate more Maillard reaction products than soft wheat under the same processing conditions.



** = 1% Significance Level (p-value 0.001-0.010)
* = 5% Significance Level (p-value 0.010-0.050)

Figure 6: Mean sensory values of the three wheat extrudates, all processed under the same conditions as Table 4.

These sensory evaluations indicate that a snack product with a better consumer preference could be obtained from low protein soft wheat compared to low protein hard wheat.

Under the conditions of this trial, extruded products produced from HYPRO hard wheats were very similar to LOWPRO soft wheat, except that their flavour attributes were less acceptable. Future trials were planned to optimise the extrusion process to improve the flavour qualities of products obtained from the LOWPRO hard wheats.

4.5 Optimisation of extruder conditions to produce an expanded product of acceptable quality using low protein hard wheat

The rationale for this trial was that, in order to get the same product from the two wheat types, identical melt temperatures would be required in the last barrel zone adjacent to the die. It was assumed that under the conditions of this trial, melt temperature would be an indication of the degree of cook of the raw material. An attempt was made to control the melt temperature at the last barrel zone by altering the barrel moisture content at given feed rate and screw speed under adiabatic conditions. In this trial extrusion runs were first made using LOWPRO soft wheat to obtain melt temperatures. Runs were then undertaken using the LOWPRO hard wheat, where moisture content was adjusted to obtain the same melt temperatures as for LOWPRO soft wheat.

Table 6: Process conditions and extruder responses of LOWPRO soft and hard wheat extrudates

Wheat variety	Feed Rate (kg/h)	Actual Barrel Moisture Calculated (%)	Extruder Responses* Melt 9 (°C) Avg.	S.D.	Die melt (°C) Avg.	S.D.	SME (KJ/Kg) Avg.	S.D.	Die Press (psi) Avg.	S.D.
	30	15.6	188.7	0.6	147.7	0.4	646.2	5.5	1014	29
	30	17.8	178.6	0.7	146.7	1.7	638.5	9.1	940	64
LOWPRO	30	20.0	171.2	0.5	142.9	0.3	605.4	4.4	849	33
Soft	25	16.1	188.5	0.5	161.8	1.0	661.2	3.6	618	31
	25	17.7	177.5	0.5	158.1	0.3	648.2	3.2	672	17
	25	19.8	168.4	0.5	152.7	0.9	636.1	3.6	643	13
	30	16.4	188.0	0.0	165.1	1.7	628.2	5.2	862	17
	30	18.9	178.0	0.2	157.4	0.5	617.7	3.7	827	22
LOWPRO	30	20.2	171.8	0.3	150.7	0.4	604.7	4.6	869	29
Hard	25	15.1	189.4	0.4	180.1	1.0	653.1	5.5	547	9
	25	18.5	177.3	0.4	172.8	0.5	606.0	2.4	620	10
	25	21.1	168.4	0.4	155.2	0.4	595.7	2.1	646	26

* Screw speed 325 rpm

The increment of 0.2-1.3 % moisture in LOWPRO hard wheat was required to obtain the same melt temperature of LOWPRO soft wheat **(Table 6) (Appendix 8)**.

A comparison of important physical attributes of products from the two wheats for one set of processing condition is shown in **Figure 7**.

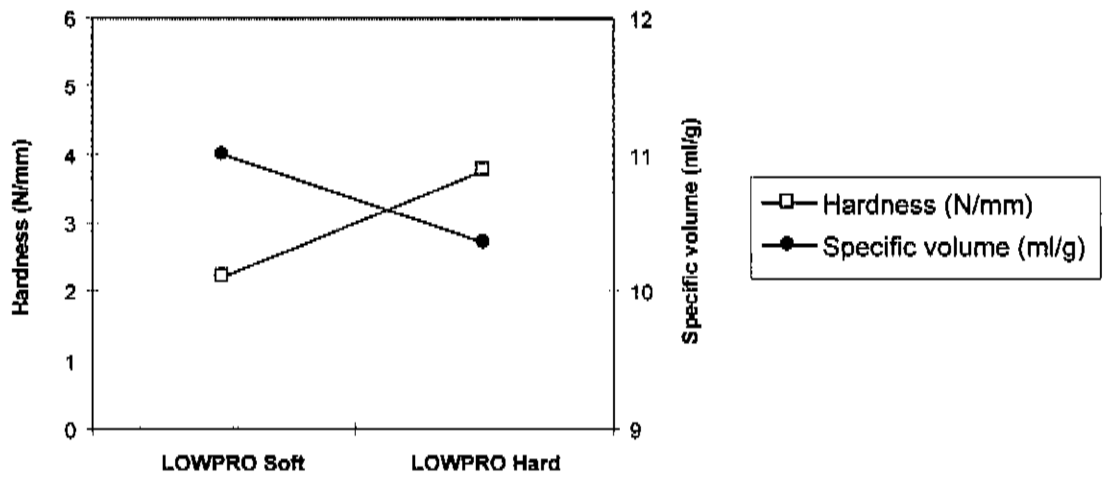


Figure 7: Overall expansion (SV) and texture (hardness) of LOWPRO soft and hard wheats, all processed under same conditions (barrel moisture 18%, melt temperature at the last zone, adjacent to die 178°C and feed rate 30 kg/h)

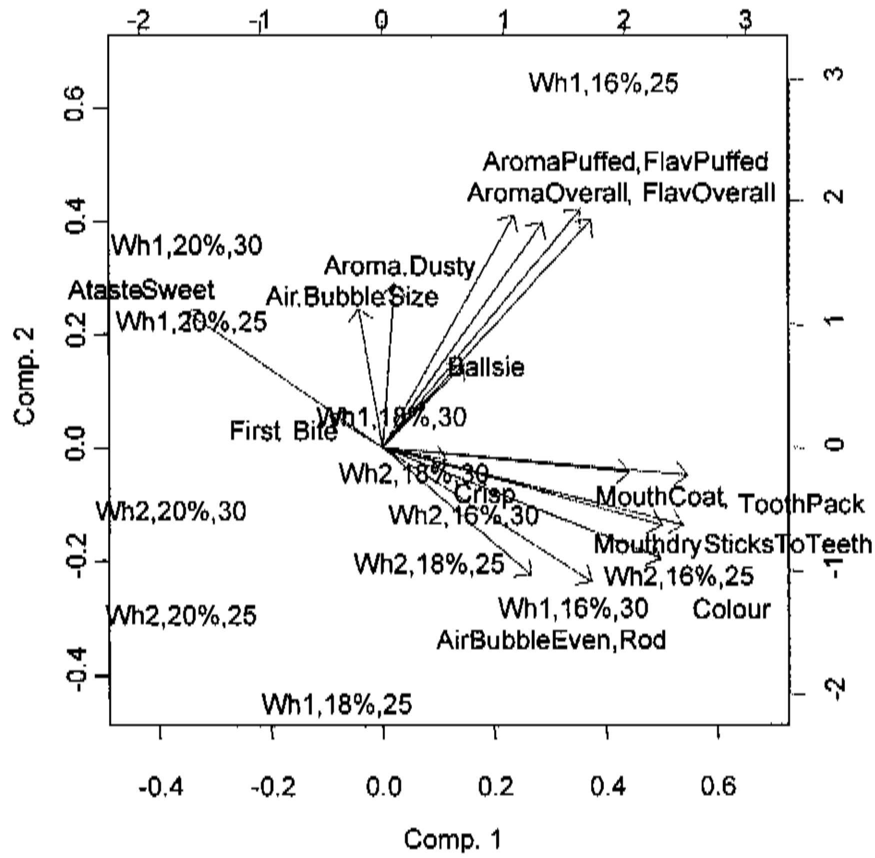


Figure 8: Mapping of sensory attributes on low protein soft and hard wheat extruded at 3 barrel moistures and 2 feed rates. (Legend Wh1 = LOWPRO Hard wheat, Wh2 = LOWPRO Soft wheat, barrel moisture %, feed rate)

Seventeen sensory attributes were measured and subjected to two principle component analyses from which biplots were obtained (**Figures 8 & 9**).

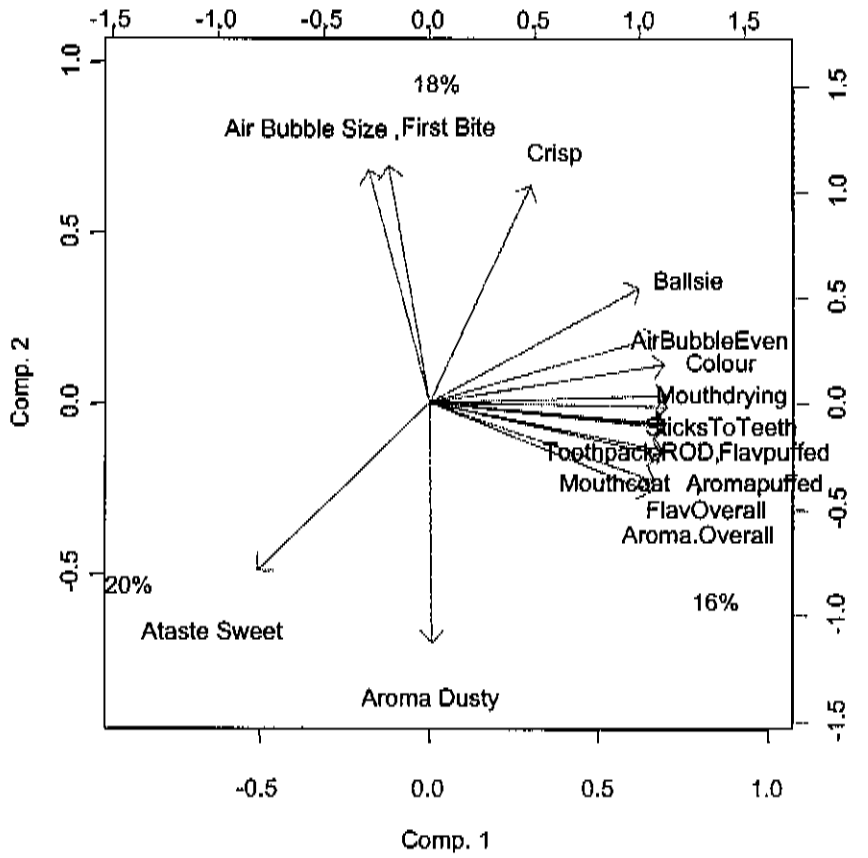


Figure 9: Mapping of sensory attributes versus 3 barrel moistures on the combined result from LOWPRO soft and hard wheat products

The desirable sensory attributes in optimised products are uniform air bubble size, first bite, crispness, air bubble evenness and colour. The less desirable ones are 'dusty aroma', strong 'puffed wheat' aroma or 'overall' aroma, strong 'puffed wheat' flavour or 'overall' flavour. Mouth coating or dryness, tooth packing or stickiness are also less desirable sensory attributes. It is likely that the less desirable flavour and aroma sensory attributes arise from the Maillard reaction products. The first biplot indicates the relationship between the individual products and the sensory attributes and the second, the relationship between the moisture settings and the sensory attributes. If the two products have similar sensory attributes they should be situated in the vicinity of each other in the first biplot.

From these plots it appears that the 18% moisture product is the crispest while the 16% has the most flavour. A barrel moisture of 18% at 30 kg/h feed rate was judged to produce the best products in terms of expansion and taste. Hence, these conditions were chosen as the optimal extruder operating condition for low protein hard wheat.

4.6 Production of a flavoured snack using low protein hard wheat

Flavoured snacks containing added maize were produced in this trial using extrusion conditions based on the findings from the previous trial. The formulation chosen was used to produce a product with more typical snack food attributes. To accommodate for the change in composition of the raw material a slightly reduced feed rate was used for the extrusion process.

In the first part of the trial four formulations based on LOWPRO soft wheat alone were extruded. The purpose of this trial was to determine optimal levels for inclusion of maize by evaluating products using sensory testing. The preference testing of LOWPRO soft wheat/maize samples were carried out by 20 untrained people (age between 24-60 yr., 13 Caucasian and 7 Asians, 14 male and 6 female). The formulations and the preference scores are tabulated in **Table 7**.

Table 7: The preference scores for low protein soft wheat/maize expanded products

PREFRENCE SCORES (number of people, %)			
LOWPRO Soft 100% Maize 0%	LOWPRO Soft 70%, Maize 30%	LOWPRO Soft 60%, Maize 40%	LOWPRO Soft 50%, Maize 50%
(5, 25%)	(7, 35%)	(7, 35%)	(1, 5%)

Based on the consumer preference score 70% or 60% wheat products clearly were the most acceptable. As the objective of the trial was to maximum the use of low protein hard wheat in the product, the 70%, 30% maize formulation was chosen for the production of a snack food based on LOWPRO hard wheat. Another 70% LOWPRO soft wheat, 30% maize formulation was run as a control (**Appendix 9**).

The extruder conditions and product characteristics are shown in **Table 8**.

These two products were coated with cheese/bacon flavour at Quest International Flavour Laboratory. Samples of these products are shown in **Figure 10**.

Sensory evaluation was conducted to determine whether panelists could detect a significant difference between the two snack food products made from wheat of differing hardness. A triangle test was used where each panelist was presented with three samples, two of one product and one of the other product. Panelists were asked to evaluate the three samples and to select the odd sample. Panelists who selected the correct odd sample in the triangle test were asked which sample they preferred and to comment on the difference(s) between the two types of samples.

Table 8: Extruder conditions and product characteristics of LOWPRO hard/Maize (70:30) and LOWPRO Soft/Maize (70:30) expanded products

	LOWPRO SOFT/Maize (70:30) %	LOWPRO Hard/Maize (70:30) %
Extruder conditions		
SME (kJ/kg)	602	601
Feed rate (kg/hr)	25	25
Barrel moisture (%)	18	18.6
Melt temperature (°C)	170	170
Product characteristics		
Specific volume (ml/g)	10.14	11.04
Radial expansion Index (REI)	2.98	3.07
Longitudinal Expansion Index (LEI)	9.11	9.30
Hardness (N/mm)	4.67	3.05
Crispness (number of + peaks)	12	15

A total of 22 panelists out of the 50 selected the correct odd sample in the triangle test. The number of correct responses necessary to establish statistical significance at the different levels in the triangle test is presented in **Table 9**.

Table 9: Number of correct answers necessary to establish level of significance for 50 Panelists

10%	5%	1%	0.1%
22	23	26	28

Although panelists did not detect a significant difference between the two products at the 5% level there was a significant difference at the 10% level.

The majority of the comments made by the panelists describing the difference(s) between the samples were on flavour (**Table 9**). There were only three comments on texture. Half of the 22 panelists perceived the product made with soft wheat as having a stronger bacon flavour than the product made with hard wheat. Four panelists perceived the hard wheat sample as having a stronger flavour than the soft wheat sample but the actual type of flavour was not specified in these comments. It is likely that they may have been referring to the cheese flavour since three other panelists specified the hard wheat product as having a more cheesy flavour. The cheese flavour may have been 'masked' by the stronger bacon flavour in the soft wheat product.

There are two possible explanations for these differences. The difference in flavour may be due to inconsistent application of the flavoured coating (batch to batch variation). Alternatively, a difference in texture between the two products may be affecting the flavour perception. That is, the softer texture may result in the perception of a more intense bacon flavour. It is possible that a combination of these explanations is also responsible.

Table 10: Summary of comments made by panelists on perceived differences between the products

LOWPRO Soft Wheat Product		LOWPRO Hard Wheat Product	
Comment	No. of Panelists	Comment	No. of Panelists
Stronger (smoky) bacon flavour	11	Less of a bacon flavour and more cheesy flavour	3
Saltier	1	Stronger flavour	4
Less flavour	2	Texture totally different, interior seemed to dissolve in mouth	1
Softer texture, less flavour	1	Shape different – slightly elongated	1
Not gluggy, did not stick to palate	1		

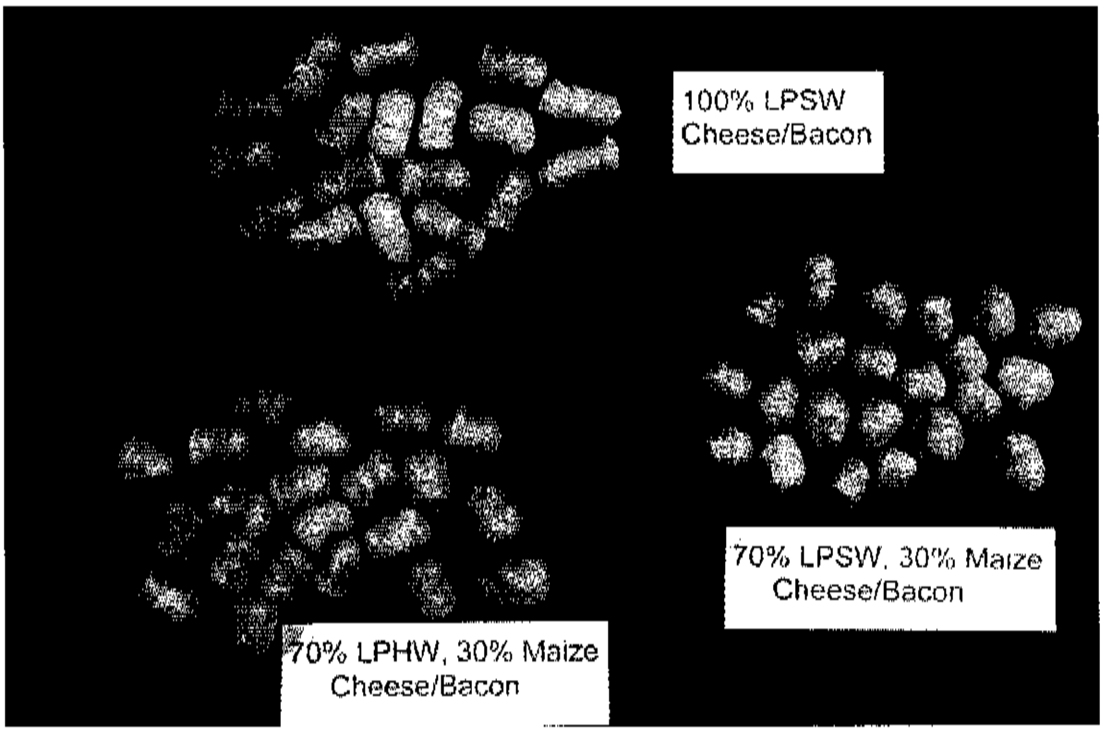


Figure 10: The optimised cheese/bacon flavour coated soft and hard wheat snacks

Of the 22 panelists who selected the correct odd sample 13 panelists preferred the hard wheat product and 9 panelists preferred the soft wheat product. In most cases, it appears that panelists discriminated between the samples on the basis of flavour.

Based on these sensory evaluations it is concluded that the product quality of low protein hard wheat expanded product is similar to low product soft wheat expanded.

The conclusion made from the overall results is that LOWPRO hard wheat can be used to substitute for LOWPRO soft wheat in the production of extruded snack foods.

5. Conclusion and Recommendations

It has been demonstrated that the low protein hard wheat can be successfully used as a replacement for the traditionally used low protein soft wheat in extruded snack products. Optimal extrusion conditions required to obtain a good product from low protein hard wheat are similar (but not identical) to those required for low protein soft wheat. This important finding has created a valuable new market for low protein hard wheat. The following topics are recommended to pursue further research for the wider acceptance of Australian wheat to service the domestic and overseas market requirement for extruded food products.

- Short barrel extruders. These extruders are widely used in the snack food industry. While arrangements were made to evaluate the low protein hard wheat in such extruders - it has not yet been possible to undertake these trials. Such trials can still be arranged and the project cannot be considered to be complete until these trials have been completed.
- Snack product quality. To further investigate the blends of Australian wheats and other ingredients to suit the expanded snack product characteristics.
- Product development. When and if there has been a satisfactory outcome from the trials with short barrel extruders, it would be an appropriate time to embark on product development with interested companies. Some co-operation with appropriate bodies in sourceing and proposing materials for these trials would be important.

6. Outcomes

In identifying the role of flour quality characteristics in the extrusion of wheat-based snack foods applicable to both domestic and export market, the following outcomes have been achieved:

- Introduction of an alternative wheat, low protein hard, in the replacement of traditionally used low protein soft wheat for the snack food using a twin screw extruder.
- Optimisation of extrusion processing conditions for the production of extruded snacks from low protein hard wheat using a twin screw extruder .

7. Acknowledgement

This work was made possible by the financial contribution of Quality Wheat CRC and in kind contribution of Food Science Australia. The authors thank Ms Di Miskelly (Project Leader), Goodman Fielder Milling and Baking and Dr Ken Quail (Program Manager), Bread Research Institute Australia for their valuable contribution to the project. We also thank Ms Maree O'Sullivan, CSIRO Mathematical and Information Sciences, PO BOX 52, North Ryde, NSW 1670 for the statistical analysis on sensory data and Quest International for the flavour application on the final products.

8. References

See **Appendix 4**.

APPENDIX 1

Analytical Test Results on six Commercial wheat flours

Table 1: Analytical data on soft (Debranning soft) and hard wheat (Bakers grist)

Description	Soft Wheat (Debranning)	Hard Wheat (Low grind)	Hard wheat (Hard grind)

Wheat variety / Grade Site	Soft NSW	Hard NSW	Hard NSW
Moisture %	13.5	14.1	13.6
Protein (N x 5.7) %	7.8	11.1	11.1
Ash %	0.59	0.46	0.48
Colour grade	-0.3	-1.6	-0.8
Maltose %	1.4	1.7	2.8
Starch damage %	4.9	6.9	10.3
Falling No. (sec)	370	440	470
RVA (Hohn Profile 4g)			
Peak Viscosity (RVU)	329	382	360
Peak Time (mins)	4.2	4.1	4.2
Holding Viscosity (RVU)	174	215	207
Final Viscosity (RVU)	360	410	396
Set Back	186	195	189
Breakdown (RVU)	155	167	153
Farinograph			
Water Absorption %	54.0	60.4	66.0
Developmesnt Time (mins)	1.5	6.7	6.6
Extensograph			
Maximum Resistance (BU)	130	470	435
Extensibility (cm)	17.1	19.9	18.2
Viscograph (250 cmg head)			
Peak Height (BU) (50g on 13.5% Moisture basis)	395	680	610
Wheat Hardness, Particle Size Index	ND	ND	ND
Malvern Particle size %	ND	ND	ND

ND not determined
Bread Research Institute, Laboratory Report No. E 4061-63, 19/08/97

Table 2: Analytical data on three wheat flours

Description	Low Protein Soft Wheat	Low Protein Hard Wheat	High Protein Hard Wheat
Wheat variety / Grade	Soft	Hard	Hard
Site	NSW	NSW	NSW
Moisture %	13.0	13.3	13.3
Protein (N x 5.7) %	7.9	8.6	12.9
Ash %	0.59	0.59	0.60
Colour grade	-0.4	-0.4	0.9
Maltose %	1.5	1.5	1.5
Starch damage %	6.0	6.9	6.9
Falling No. (sec)	363	514	660
RVA (Hohn Profile 4g)			
Peak Viscosity (RVU)	337	342	288
Peak Time (mins)	4.7	4.2	4.2
Holding Viscosity (RVU)	220	214	166
Final Viscosity (RVU)	427	419	344
Set Back	207	205	178
Breakdown (RVU)	117	128	122
Farinograph			
Water Absorption %	57.6	58.9	65.9
Developmesnt Time (mins)	1.5	1.5	7.0
Extensograph			
Maximum Resistance (BU)	190	465	610
Extensibility (cm)	15.8	14.8	18.5
Viscograph (250 cmg head)			
Peak Height (BU) (50g on 13.5% Moisture basis)	700	1220	1050
Wheat Hardness Particle Size Index	14.5	17.5	22.5
Malvern Particle size %			
D(v,0.1)	9.0	12.0	19.4
D(v,0.5)	54	68	81
D(v,0.9)	153	156	166
D(4,3)	69	77	88
Vol<40µ	43	33	22

Bread Research Institute, Laboratory Report No. F0958-63, and Goodman Fielder Mills, Summer Hill

APPENDIX 2

Analytical Test Results on a Commercial Maize Flour

Table 1: Analytical data on a commercial maize flour

Description	Maize flour Polenta
Variety/Grade	
Site	NSW
Moisture %	13.0
Protein (N x 5.7) %	7.9
Ash %	0.59
Fat %	ND
Sieving Test %	
Retained 500 micron	51.2
Retained 355 micron	38.1
Retained 212 micron	6.5
Retained 150 micron	1.4
Throughs	2.8
Malvern Particle size %	
D(v,0.1)	259
D(v,0.5)	453
D(v,0.9)	723
D(4,3)	490
Vol<40µ	2

ND not determined

APPENDIX 3

Extruder Overview

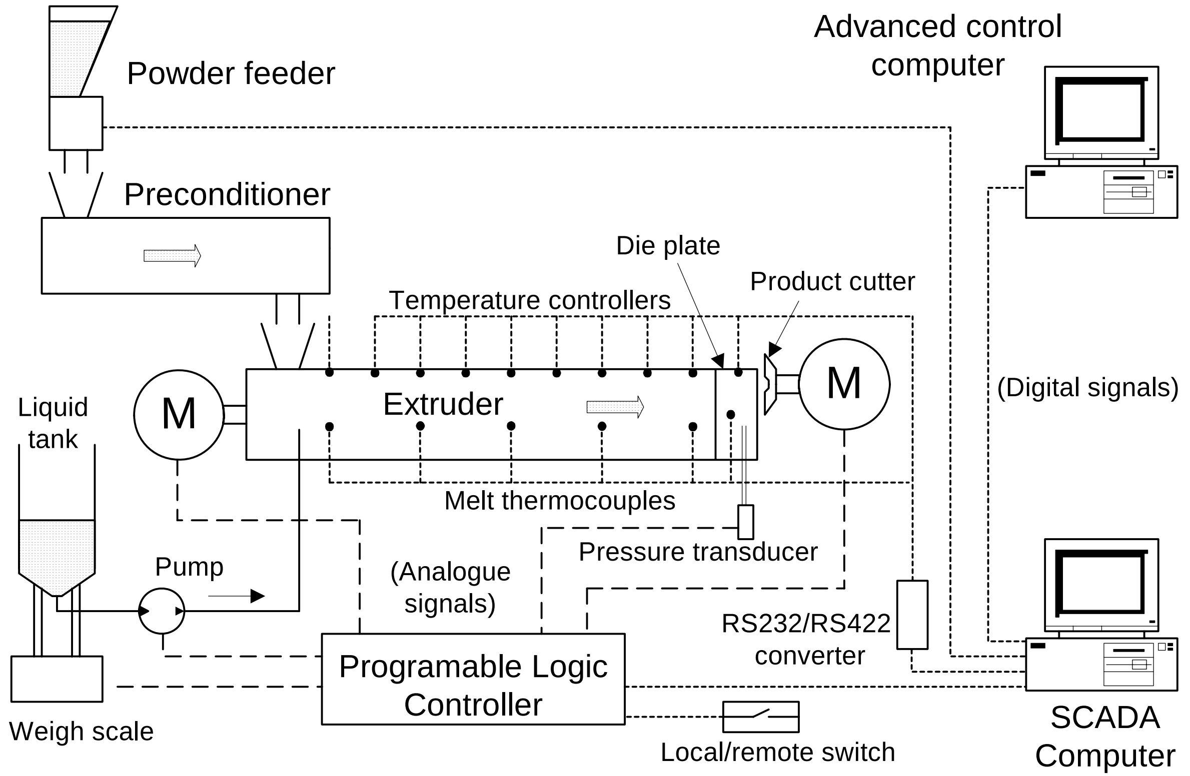


Figure 1: Schematic diagram of the extruder, showing some on line data collection and control points

APPENDIX 4

Literature Review of the Effect of Wheat Type and Form of Cereals on the Properties of the Extrudate

The Effect of Type and Form of Cereals on the Properties of the Extrudate

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1. Introduction

Australia is the fourth largest wheat exporter in the world, following only the US, Canada and the EU. The industry has excellent positions in many of the most attractive wheat markets in the world, particularly in Asia. Australian medium and low protein wheats are strongly suited to these Asian noodle markets. However, Australia is unable to produce quantities of high protein wheat, used for pan bread, in many instances it is unable to ensure consistent supply of high protein wheat to customers.

Growing regions are distributed around the temperate coastal areas of Australia, varying substantially as a result of climate, particularly when drought conditions exist. Over the ten years to 1997-8, the average proportions were Western Australia, 42%; New South Wales, 24%; Victoria, 10%; South Australia, 16% and Queensland 8%. There are over 45 thousand registered growers and three major millers.

The most frequent wheat quality criteria are protein, hardness, colour and moisture, while the common delivery criteria are cleanliness, added moisture, admixture, consistency and availability. Australian wheat has an average protein level of 9-10.5%, compared with 10.5-13% for US product and 11.5-15% for Canadian. The high protein wheat tends to dominate in starch and gluten, bread and pasta. Nevertheless, because of its suitability to noodles and flat bread, Australia has solid shares in relatively attractive Asian and Middle Eastern markets. Australian grain protein levels have been declining gradually for many years associated with slowly rising average wheat yields.

In response to this situation, the Australian Wheat Board has launched the '2 x 10 x 2000' campaign, which aims to increase yields to 2 tonnes/ha and protein to 10% by the year 2000 (Grain Council of Australia, 1995).

Historically, Australia was a producer of mainly soft wheat, but soft wheat production has been declining for many decades, so that the vast majority of the crop is now hard wheat. Hard wheat is considered more saleable on the export market, where it is preferred for flat bread and yellow alkaline noodles. Soft wheat (strong types) is used for white salted noodles and soft wheat (weak type) is used for biscuit, cakes and snack foods.

It is against this background that the potential use of hard wheat in extrusion is of interest to the wheat and processing industries.

2. Effect of variety, geographical location and type

Conditions known to alter the extrusion behaviour of cereals include variety, milling and conditions for storage of flour. The variety or the biochemical components (starch, protein, lipid and water) of a material to be extruded affect the properties (texture, structure and expansion) of the extrudate. In general terms, the starch content has a positive effect on expansion, the other three components have a negative effect. The cell structure is most affected by protein and starch and least affected by lipids. The effect of location, variety and type of cereals on the extruder response and extrudate properties are summarised in **Table 1**.

Table 1: The effect of variety, geographical location and type of cereals on extrudate properties

Cereal type / variety / location	Power requirement	Expansion	Texture	Structure	Reference
Soft wheat[a], 9 % protein	low	high	medium	large & small cells	Faubion and Hoseney,1982a
Hard wheat[a], 11.2 % protein	low	medium	hard	large & small cells	
Hard wheat[a], 15.3 % protein	high	unstable	soft	rough cell wall	
Hard red spring wheat[b], Minnesota					Sutheerawttananonda *et al*., 1994
Butte 86, 13.3 % protein	ND	high	ND	low cell density	
Butte 2371, 13.8 % protein	ND	high	ND	low cell density	
Grandin, 13.3 % protein	ND	high	ND	low cell density	
Hard red spring wheat[b], North Dakota					
Butte 86, 13.9 % protein	ND	low[b]	ND	high cell density	
Butte 2371, 12.9 % protein	ND	low[b]	ND	high cell density	
Grandin, 13.4 % protein	ND	low[b]	ND	high cell density	
Wholewheat[c],					Antila *et al*., 1983
Diplomat, 14.1 % protein	high	low	hard	ND	
Maris Huntsman, low baking quality	low	high	soft	ND	
Rice flour[d]					
Waxy rice, 0.3% Amylose, 6.9% protein	ND	non expanded	soft	ND	Kadan *et al*., 1997
Caltrose-medium, 16.7% Amylose, 7.1% protein	ND	non expanded	hard and gummy	ND	
Perboiled long grain, 21.0% amylose, 8.6% protein	ND	non expanded	hard and gummy	ND	
Barley[e](ground)					Berglund *et al*., 1994
Wanubet, 12.9% protein,2.82% fat	ND	medium low	ND	ND	
Apollo, 16.4% protein, 2.41% fat	ND	low	ND	ND	
Bowman, 12.6% protein, 2.50% fat	ND	medium high	ND	ND	
Tupper, 14.7% protein, 1.69% fat	ND	high	ND	ND	

a	175°C / 100rpm	Single screw extruder, Brabender
b	180°C / 350rpm	Twin screw extruder, 16D, Wenger
c	160°C / 120rpm	Twin screw extruder, 60cm long screws, Creusot-Loire
d	90°C / 60rpm	Single screw extruder, Brabender
e	125°C / 410rpm	Twin screw extruder, 15D, Wenger

ND Not determined

The starch and gluten types are not the important factors in determining the extrusion characteristics of flour. Faubion and Hoseney isolated gluten from both soft and hard wheat flours and added to soft wheat in amounts sufficient to bring its final protein content to the level of hard wheat. When these gluten-supplemented flours were extruded their expansion and power requirements were similar to those of the high protein hard wheat. This suggested that differences among flours were due primarily to gluten quality rather than to source (Faubion and Hoseney, 1982a).

Sutheerawttananonda *et al*., reported that depending on the location in which the wheat is grown, the same wheat cultivar can show significant differences in extrusion characteristics such a bulk density, expansion ratio, air cell size and density. It has been suggested that environmental factors such as weather, soil type, annual rainfall, and sunshine affect the wheat flour compositions and milling yield. It may also alter the shape and functionality of major flour components through the structure of wheat kernels (Sutheerawttananonda *et al*., 1994).

It was suggested that high protein grains have a thicker barrier around the starch granules. It slows the water intake and results in slower gelatinisation and retard swelling of granules. This leads to more water available to be lost as steam during extrusion and the result is a hard product (Kadan *et al*., 1997).

The expansion of cereals produced by extrusion of barley had limited expansion and bulk density increased with increasing protein and lipid content. The hydration capacity decreased with increasing lipid content and bulk density. The protein and lipid content also affect the alkaline viscosity of the extrudate. The alkaline extract viscosity of barley and its associated β-glucan content relate both to functional quality in food products and to health effects. (Berglund *et al*., 1994).

3. Effect of particle size

The effect of particle size on extrudate properties is shown in **Table 2**. In general coarser particles require more work to break down and result a higher mass temperature. Thus flour mass viscosity is reduced. Motor torque which is increased by the larger amount of work put into the coarser flour is reduced by the lower viscosity of the flour mass. The net result is that the increase in torque with particle size is too small to be statistically significant. The product from coarser flour expands to a larger volume, though this difference is not large enough to show significant effects on length and diameter measurements (Guy *et al*., 1984).

The effect of particle size on the processing conditions has been studied by Guy *et al*., 1984. The effect of particle size was small for the high shear screw configuration where the different shearing properties of the particles gave slightly greater expansion for the coarser wheat flours. In the other type employing low shear configuration, particle size had no effect until the screw speed was very high. The intermediate-sized wheat flours gave an enhanced expansion at high speeds compared with the fine or coarse flours.

The particle size of rice flour has a significant effect on the physical and chemical properties of the extrudate. Expansion ratio increased and bulk density decreased as particle size decreased. Hardness decreased and air cell size became uniform as particle size decreased. Gelatinisation and partial dextrinisation occurred during extrusion and the degree of dextrinisation was influenced by particle size (Ryu and Lee, 1988).

Table 2: The effect of particle size on extrudate properties

Flour type	Expansion	Texture	Sensory/Structure	Reference
Waxy Hull-less Barley[a]				Dudgeon-Bollinger *et al.*, 1997
4/64 inch particle size, 14.9% protein, 3.8% fat, 55.9% starch	medium low	medium hard	crispy	
pearled, 4/64 inch particle size, 12.7% protein, 1.8% fat, 63.9% starch	medium high	Medium soft	crispy	
>150µm particle size, 12.3% protein,1.3% fat, 60.3 % starch	low	hard	crispy	
<150µm particle size, 12.1% protein, 1.6% fat, 65.9% starch	high	soft	less crispy	
Wheat flour[b]				Guy *et al.*, 1984
A, 324µm, 9.9% protein, 1.7% fat, 0% damaged starch	medium low	ND	ND	
B, 191µm, 9.8% protein, 1.9% fat,1% damaged starch	medium low	ND	ND	
C, 136µm, 9.9% protein, 1.7% fat, 7.5% damaged starch	high	ND	ND	
D, 26µm, 10.1 % protein, 1.7% fat, 17% damaged starch	low	ND	ND	
Rice flour[c]				Ryu and Lee, 1988
18 mesh particle size	low	hard	large & small cells	
120 mesh particle size	high	soft	uniform cells	

a 150°C / 300rpm, Twin screw extruder, 15D, Wenger
b 180°C / 300rpm, Twin screw extruder, 15D, APV
c Single screw extruder

ND Not determined

4. Effect of storage temperature

The effects of ageing of flour and grain was found to lead to considerable changes on performance in the extrusion process (**Table 3**). Flours tends to change in performance when stored at ambient temperature but remain unchanged at -11°C. Flours freshly milled from stored grain gave similar performances throughout the storage period at ambient temperature. The changes tend to increase the frictional effects of flours, required more energy input and increase in expansion. The increase in energy input increases the number of gas cells and length/diameter ratios as the texture become finer. The changes, which apply both to white and wholemeal flours, are gradual and show a fairly linear increase with time (Guy *et al*., 1987).

Table 3: The effect of storage temperature on extrudate properties

Flour type	Power requirement	Specific volume	Expansion	Sensory/ Structure	Reference
Soft wheat[a]					Guy *et al*., 1987
white flour, control	low	low	fatter	low cell density	
white flour, ambient temp, 12 months	high	high	slimmer	high cell density	
white flour, -11°C temp, 12 months	unchanged	unchanged	unchanged	unchanged	
wholemeal, control	low	low	fatter	low cell density	
wholemeal, ambient temp, 12 months	high	high	slimmer	high cell density	
wholemeal, -11°C temp, 12 months	unchanged	unchanged	unchanged	unchanged	

a 150°C / 300 & 450 rpm, Twin screw extruder, 15D, APV
ND Not determined

5. Effect of cereal type

Ingredients, which are commonly, used in snack products are wheat, maize and rice. A combination of these ingredients and some additional minor ingredients are usually added to the snack formulations. Each ingredient has different functionality, which influenced the snack product quality. Rice and maize derivatives created a more severe processing environment, causing higher heat and shear inputs, than soft wheat flour. They showed more extensive development as a fluid, and expanded to greater specific volumes than wheat flour and gave finer cell structures, under comparable machine settings. Generally the wheat flour extrudates were significantly harder, and those of rice flour softer, than maize, for equivalent process stages and formulations. The wheat flour products were significantly more crunchy. They formed denser extrudates with coarser textures. The well expanded maize and rice products tended to be more finely textured and had lower crunchiness scores than wheat flour products. Wheat flour extrudates tended to be more gummy than rice and maize, in low sugar systems (Guy *et al*., 1993).

The effect of differences between cereal is summarised in **Table 4**.

Table 4: The effect of different cereals on extrudate properties

Cereal type[a]	Power requirement	Expansion	Texture	Structure	Reference
Hard wheat	high	medium low	ND	ND	Guy *et al*., 1993
Soft wheat, 10.9% protein, 1.7% fat	low	low	coarse texture	large cells	
Maize grits, 7.5% protein, 1.3% fat	high	high	medium texture	large & small cells	
Rice flour, 8.0% protein, 1.6% fat	high	medium low	fine texture	fine cells	

Cereal type[b]	Power requirement	Expansion	Water Solubility Index	Water Absorption Index	Reference
Wheat starch, adjusted to 8% fat	high	high	high	low	Singh and Smith, 1997
Whole wheat meal, adjusted to 8% fat	medium	medium	medium	medium	
Oat flour, 8% fat	low	low	low	high	

Cereal type[c]	After Extrusion		Reference
	Nitrogen Solubility	Protein Digestibility	
Sorghum (high tannin), 12.5% protein, 3.7% fat	unchanged	unchanged	Dahlin & Lorenz, 1993a,1993b
Sorghum (low tannin), 11.6% protein, 3.1% fat	decreased	improved	
Millet, 12.3% protein, 4.1% fat	decreased	improved	
Quinoa, 17.3% protein, 4.9% fat	increased	improved	
Wheat, 16.1% protein, 1.1% fat	increased	improved	
Rye, 16.1% protein, 1.8% fat	increased	improved	
Corn, 10.9% protein, 3.8% fat	decreased	improved	

a 150°C / 300 & 450 rpm Twin screw extruder, 15D, APV
b 175°C / 300 rpm Twin screw extruder, 15D, APV
c 150°C / 150 rpm Single screw extruder, 20D, Brabender

When wheat flour is compared with oat flour, wheat flour requires higher energy input than oat flour, based on the same lipid content and under comparable machine settings. In terms of expansion, oat flour is significantly lower than wheat flour. However, at temperatures higher than 125°C the expansion increased with the increase in moisture, which is the opposite of the expansion nature of wheat. Water solubility index of wheat product increases with temperature whereas oat varies little with temperature and moisture changes on processing conditions (Singh and Smith, 1997).

Nitrogen solubility of six cereal grains and quinoa were examined. Extrusion in general, improved nitrogen solubility of wheat, rye and quinoa. Decreased protein solubility has been associated with partial or total denaturation of protein. It is believed that there is a particular water-soluble protein in the three grains at the starch-protein interface. It is possible that extrusion processing partially disrupts the starch-protein interface, exposing water-soluble proteins, which results in the product with an increased solubility profile (Dahlin & Lorenz, 1993a, 1993b).

6. Effect of different cereal composition and treatment

Different treatment or different compositions of a cereal within a variety is likely to affect the behaviour of an extrudate. The effect of differences within varieties on extrudate properties are shown in **Table 5**.

The effect of different temperatures on the extrusion behaviour of wheat flour from sound and sprouted wheat (24 and 48h) has been studied. The diameter of the extrudates prepared from wheat flour from sound grains decreased, but density increased, with the increase in temperature of the extruder die section. However, the use of wheat flour from sprouted grains resulted in increased expansion and decreased density of the extrudates. The specific energy requirements decreased by 25 and 23% with the increase in temperature of die section from 145°C to 190°C in flours from sound and 48h sprouted grains, respectively. Extrudates from wheat flour of sprouted grains were softer in texture and those of 48h sprouted wheat showed higher overall acceptability scores, as compared to those of sound wheat. The presence of gluten in wheat usually results in a hard product. The breakdown of gluten proteins during sprouting by proteolytic enzymes may have contributed to the softness of extrudates prepared using the flour from sprouted wheat (Singh *et. al*., 1994).

The degree of expansion generally decreased with increase in added protein or lipids. Water solubility index of the corn meal products significantly decreased with increase in protein. The decrease in water solubility index of corn meal extrudates, due to increase in protein, was explained as the effect of dextrinisation owing to extrusion cooking (Cornway & Anderson, 1973).

Since chlorination is known to improve flour functionality in cake baking, an investigation of the behaviour of bleached flour in the extrusion process, with particular reference to the starch component was reported by Paton and Spratt (1978). Relatively low pressure and low shear screw configuration was used for the study. The untreated flour does not attain the same high initial viscosity, as does the chlorinated flour. Differences in the viscosity characteristics of extruded products are likely to be a function of the distribution of water in the system and may be influenced by the effects of chlorine on wheat flour lipids and on the sulfhydryl bonds in wheat protein (Paton and Spratt, 1978).

Table 5: The effect of differences within varieties on extrudate properties

Cereal type	Power requirement	Expansion	Texture	Structure	Reference
Sound wheat[a]	high	low	hard	high cell density	Singh *et al*., 1994
Sprouted wheat[a]	low	high	soft	low cell density	

Cereal type	Expansion	Water absorption index	Water solubility index	Reference
Corn meal[b] 9.4% protein, 0.2% fat	high	high	high	Cornway & Anderson, 1973
Whole ground corn meal[b] 11.3% protein,1.8% fat	low	low	medium	
Whole ground high lysine corn meal[b] 10.6% protein,2.4% fat	medium	high	low	

Cereal type	Viscosity of extrudate starch paste	Reference
Soft wheat[c]		Paton and Spratt, 1978
Chlorinated (pH = 4.93)	increased	
Unchlorinated (pH = 5.70)	decreased	

a	125°C / 100 rpm	Single screw extruder, 20D, Brabender
b	120°C / 700rpm	Single screw extruder, Wenger
c	163°C / 100rpm	Single screw extruder, Wenger

7. Effect of composition

7.1 Protein

Extrusion processing can alter protein structure and solubility by heat shear force, pressure and oxygen. It can also influence the protein digestibility of the product. Protein enrichment of buckwheat flour with nonfat dry milk ingredients resulted a decrease in expansion, water holding capacity and protein digestibility, when compared to buckwheat products. The protein-enriched products were harder and evaluated as low general acceptability scores (Rayas-Duarte *et al*., 1998).

Studies on the effect of heat on wheat protein interactions have shown that the sulfhydryl-disulfide interchange reaction was responsible for the protein network formation upon thermosetting. Addition of disulfide reducing agent (cysteine) during extrusion markedly affected physical and chemical properties of wheat flour extrudate. Radial expansion at the die decreased in linear extrudates and longitudinal expansion through surfaces cut at the die increased, reflecting weakened dough strength. Cell size decreased, cell walls thinned, and cells became more evenly distributed and densely packed (Koh et al., 1996).

In the presence of a large excess of added cysteine, the sulfhydryl group in cysteine could break the native interchain disulfide bonds of gluten to produce protein-SH or protein-SS-cysteine and greatly reduce the molecular weight of gluten. Also, the disulfide cross-linking between protein and protein was inhibited by the interaction of cysteine and protein during extrusion processing. As a result, the reduction in the extent of cross-linking between protein molecules made the extrudate possess a weakened network, which could not resist the stretching of the cell wall caused by gas expanding at the die. The cell size and the cell wall thickness decreased to a level which could be supported by the strength of the weakened network (Li & Lee, 1996; Koh et al., 1996).

On the other hand, the addition of cysteine, as a precursor to extrusion cooking, generates numerous sulphur-containing compounds (Bredie *et al*., 1997). The concentration of most volatiles increased with cysteine addition. Among them meat like flavour compounds were collected in the highest amounts at the die of the extruder (Hwang *et al*., 1997).

The effect of protein composition on extrudate properties is summarised in **Table 6**.

Table 6: The effect of protein composition on extrudate properties

Cereal type	Water Holding Capacity	Expansion	Texture	Structure / Sensory	Reference
Light buckwheat flour / wheat flour / nonfat dry milk blends					
Blend 1[a] (55:40:5), low protein	high	high	soft	low general acceptability score	Rayas-Duarte *et al*., 1998
Blend 2[a](40:55:5), medium protein	medium	medium	medium	medium “ “ “	
Blend 3[a](30:60:10), high protein	low	low	hard	high “ “ “	
Wheat flour[b], 0.0% cysteine added	high	high	medium low	thick cell wall, large cell	Li & Lee, 1996
Wheat flour[b] 0.5% cysteine added	medium	medium	low	medium cell wall, medium cell	
Wheat flour[b] 1.5% cysteine added	low	low	hard	thin cell wall, small cell	

Cereal type	S-H content	Expansion	S-S content	Structure / Sensory	Reference
Wheat flour[c], 0.0% cysteine added	low	high	low	thick cell wall, large cell	Koh et al., 1996
Wheat flour[c] 1.0% cysteine added	medium	medium	medium	medium cell wall, medium cell	
Wheat flour[c] 2.0% cysteine added	high	low	high	thin cell wall, small cell	

Cereal type	Aroma profile (major aromas in bold)	Reference
Soft wheat flour[d], 9.5% protein	**Biscuity**, **Cornflakes**, **Sweet**, Nutty/roasted and **Cooked milk**	Bredie *et al*., 1997
(“ + cysteine + glucose)[d]	**Popcorn**, **Nutty/roasted**, **Puffed wheat**, rubbery and sulphury	
(“ + cysteine + xylose)[d]	**Popcorn**, **Nutty/roasted**, **Puffed wheat**, rubbery and sulphury	
(Starch + cysteine + glucose)[d]	**Cooked apple**, wet washing, sharp/acidic and stale cooking oil	
(Starch + cysteine + xylose)[d]	**Cooked apple**, wet washing, sharp/acidic and stale cooking oil	
Wheat flour[e] 0.25% cysteine added	low total volatiles, low sulphur-containing compounds	Hwang *et al*., 1997
Wheat flour[e] 0.5% cysteine added	medium total volatiles, medium sulphur-containing compounds	
Wheat flour[e] 1.05% cysteine added	high total volatiles, high sulphur-containing compounds	

a	150°C / 390 rpm	Twin screw extruder, 15D, Wenger
b	185°C / 500 rpm	Twin screw extruder, 30D, Werner Pfleiderer
c	185°C / 500 rpm	Twin screw extruder, 29.3D, Werner Pfleiderer
d	160°C / 350 rpm	Twin screw extruder, 50D, APV
e	185°C / 500 rpm	Twin screw extruder, 30D, Werner Pfleiderer

7.2 Lipids

Lipids such as monoglycerides and fatty acids are added to starchy foods to obtain desired functional characteristics in the end products. Presence of lipids in starchy foods results in formation of amylose-lipid complex during processing of these foods. In general, adding lipids to cereal extrusion decreases power requirement (SME) and expansion. However, modification of cell structure (pore size distribution and pore volumes) is achieved, depending on the type of lipids used. The effect of lipid on properties of cereal extrudates is shown in **Table 7**.

The role of lipid in the extrusion cooking of medium protein and high protein hard wheat flours was assessed. Lipids were removed from medium protein and high protein hard wheat flours. Both defatted flours gave better expansion than their unextracted controls. Reconstitution or adding of lipids decreased expansion, shearing and breaking strength. Reconstituted flours gave ultrastructures equivalent to those of their unextracted controls. Subtle changes were found in the structure of the defatted, high protein flour extrudates. By exchanging the source of lipids and extruding the reconstituted flour the differences observed were due to the differences in the flour and not the extracted lipids (Faubion & Hoseney, 1982b).

Nine different lipids were used to study the modification of microstructure of extruded corn starch. Addition of lipids (coconut, palm and peanut oil) resulted in modification of pore size distribution and pore volumes. Complexing lipids (behenic, stearic, myristic and monoglycerides) gave lower pore volumes, smaller size pores, lower porosities and higher shear strengths of the extrudates. The study have shown that extrudate bulk density increased and porosity decreased when lipids complexed with amylose. It is not yet known that why the porosity increased and shear strength decreased for peanut, coconut and palm oils as compared to the control. However, X-ray diffraction patterns of starch extruded without any lipid and starch extruded with peanut, palm and coconut oils were almost similar. The diffractograms show that A-pattern observed for cereal starches was completely lost and a V-pattern appeared. This was indicated by peaks at $2\theta = 7.3°$, 12.6° and 19.8° which was probably due to the formation of complexes between amylose and native lipids. With fatty acid and monoglycerides, a distinct V-pattern was observed. The peak heights progressively increased as the fatty acid chain length decreased from 22 carbons for behenic acid to 14 carbons for myristic acid indicating greater degree of complex formation (Bhatnagar & Hanna, 1997).

The effect of the addition of fatty acids, monoglycerides (MG) and wheat germ oil (WGO)on the level of crystallinity and the crystalline structure of extrusion cooked wheat starch have been studied using a twin screw extruder. Measurements of water solubility and water absorption indices were made on the extrudates, together with specific mechanical energy (SME) consumption and die pressure for the extruder. MG and the fatty acids added to a level of 4% caused an increase in $V_{hydrate}$ type crystallinity. WGO addition to a level of 8% caused no change in crystallinity, although the $E_{hydrate}$ type was favoured at lower moisture contents. All additives caused a decrease in SME and an increase or maximum in die pressure. WGO behaved differently than MG and fatty acids in that its addition caused the water solubility index and expansion to increase, as previously observed for other oils added to flours (Singh *et al*., 1998).

Table 7: The effect of lipids on properties of cereal extrudates

Flour type	Power requirement	Expansion	Texture	Structure	Reference
Hard wheat[a], 11.2 % protein	ND	medium	hard	large & small cells	Faubion & Hoseney, 1982b
Petroleum ether defatted	ND	high	harder	large, rough & fibrous cells	
Reconstitited	ND	medium	hard	large & small cells	
Hard wheat[a], 15.3 % protein	ND	medium	hard	large, rough & fibrous cells	
Petroleum ether defatted	ND	medium high	harder	large, rough & fibrous cells	
Reconstitited	ND	medium	hard	large, rough & fibrous cells	

Cereal type	Amylose lipid complex formation	Expansion	Texture	Structure	Reference
Corn starch[a], 25% Amylose, 0.3% protein, 0.1% lipid	control	control	control	control	Bhatnagar & Hanna, 1997
(“ + Behenic acid)[a]	more	reduced	harder	decreased pore volume, smaller pore size	
(“ + Stearic acid)[a]	more	reduced	harder	decreased pore volume, smaller pore size	
(“ + Myristic acid)[a]	more	reduced	harder	decreased pore volume, smaller pore size	
(“ + Coconut oil)[a]	unchanged	increased	softer	increased pore volume, larger sized cells	
(“ + Palm oil)[a]	unchanged	increased	softer	increased pore volume, larger sized cells	
(“ + Peanut oil)[a]	unchanged	increased	softer	increased pore volume, larger sized cells	
(“ + Monoglycerides)[a]	more	reduced	harder	decreased pore volume, smaller pore size	

Cereal type	Power requirement	Expansion	Water Solubility Index	Water Absorption Index	Reference
Wheat starch[b]	high	low	low	high	Singh *et al*., 1998
(“ + 4%Wheat germ oil)[b]	medium	medium	medium	medium	
(“ + 8%Wheat germ oil)[b]	low	high	high	low	

a	140°C / 140 rpm	Single screw extruder, 20D, Brabender
b	175°C / 300 rpm	Twin screw extruder, 50D, APV

7.3 Ingredients

Many food snacks combine crispness and hardness in texture and are obtained by extrusion cooking using complex recipes with various ingredients (proteins, emulsifiers, minerals, aromas, flavouring, etc). Investigation of the relationships between the nature of ingredients and textural properties of extrudates are becoming increasingly important as the demand of new snack-type product increases. The effect of ingredients on physical and structural properties of wheat flour is tabulated in **Table 8**.

The influence of three ingredients (bran, sucrose and magnesium carbonate) commonly used in extrusion-cooking of wheat flour type formulation has been reported. Generally the apparent density of an extrudate increases with concentration of any ingredient increased. Cell number per pixel area increased greatly while average cell size decreased as bran concentration increased from 0 to 16%. Average cell size increased as magnesium carbonate increased from 0-0.4%, but cell size decreased above 0.4%. Bran interfered with bubble expansion reducing extensibility of cell walls and causing premature rupture of steam cells at a critical thickness related to the particle size of bran. This would prevent formation of large cells. With sucrose, availability of water is reduced as sucrose absorbs more water than wheat starch. Thus, less steam was available to feed expanding cells during the flashing process. At low concentrations of $MgCO_3$ (below 0.4%), magnesium ions enhanced protein-water interactions by reacting with protein charges. This decreased the electrostatic attraction between opposite charges of neighbouring molecular segments. Thus, magnesium ions allowed protein macromolecules to unfold, and thus increase the viscosity of the cooked dough, which tended to give large cells. At concentrations of $MgCO_3$ above 0.4%, competition occurred between proteins and magnesium ions for available water molecules. Due to strong bonds between water and salt, there were not enough water molecules for protein solvation. Thus, protein-protein interactions became stronger than protein-water interactions. This effect, combined with nonavailability of water, resulted in reducing expansion of cells at higher levels of magnesium carbonate (Moore *et al*., 1990).

The effect of six baking ingredients (sucrose, nonfat dry milk [NFDM], whole egg powder, shortening powder, glyceryl monostearate [GMS], sodium bicarbonate [SBS]) on expansion, bulk density, breaking strength and cell structure of wheat flour extrudates have been studied. The sectional expansion index (SEI) and longitudinal expansion index (LEI) were significantly affected by both sucrose and GMS (*P* less than 0.01). Interaction of shortening powder and GMS had significant effects on the LEI (*P* less than 0.01), and the sucrose-egg interaction affected the SEI (*P* less than 0.05). Bulk density was significantly affected by sucrose, shortening powder and GMS (*P* less than 0.05). Sucrose and shortening powder had significant effects on breaking strength and cell structure. On the other hand, within the observed concentration ranges, NFDM, egg powder, and SBC had no significant effects on extrudate properties. Therefore, the physical and structural properties of wheat flour extrudates can be controlled by changing the concentrations of sucrose, shortening powder and emulsifier (Ryu *et a*l., 1993).

Table 8: The effect of ingredients on physical and structural properties of wheat flour

Cereal type	Apparent density	Apparent viscosity	Texture	Structure	Reference
Wheat flour[a]	control	control	control	control	Moore *et al*., 1990
(" + bran)[a]	increased	unaffected	harder	cell density increased, cell size decreased, more spherical cells	
(" + Magnesium carbonate)[a]	increased	increased	unaffected	cell density increased, cell size decreased, more elongated cells	
(" + sucrose)[a]	increased	decreased	harder	Not determined	
Cereal type	**Radial expansion**	**Volume expansion**	**Texture**	**Structure**	
Hard winter red wheat[b], 11.6% protein	control	control	control	control	Ryu *et a*l., 1993
(" + sucrose)[b]	decreased	decreased	harder	cell density increased, cell size decreased	
(" + NFDM)[b]	unaffected	unaffected	unaffected	unaffected	
(" + egg)[b]	unaffected	unaffected	unaffected	unaffected	
(" + shortening powder)[b]	decreased	decreased	harder	cell density increased, cell size decreased	
(" + GMS)[b]	decreased	decreased	unaffected	cell density increased, cell size decreased	
(" + SBC)[b]	unaffected	unaffected	softer	unaffected	

a 150°C / 200 rpm Twin screw extruder, 500mm screw length, Clextral
b 130°C / 400 rpm Twin screw extruder, 15D, Wenger

NFDM Nonfat dry milk powder
GMS Glyceryl monostearate
SBC Sodium bicarbonate

8. Effect of extruder size and type

A comparison of the extruder responses and product characteristics processed on Clextral BC45 and BC72 extruders have been reported. Mean residence times were found to be equivalent on both machines, depending on feed rate. For the product characteristic, a 35% water solubility level could be achieved in the BC45 at 200 rpm with a feed rate of about 27 kg/hr if using one reverse screw element. For the same product in the BC 72 at 130 rpm the feed rate could reach 80 kg/hr with one reverse screw element (Barres *et al*., 1990).

The study of starch transformation in laboratory scale (APV MPF-19) and pilot scale (APV MPF-50) extruders have been reported. The crystallinity of the product from the larger extruder generally decreased compared to the smaller extruder. The larger throughput in bigger extruders have less heat transfer per surface area and making it much more difficult to achieve uniform heating of the feed material. This theory was supported by the presence of ungelatinised maize grits in the product of the larger extruder (Cairns *et al*., 1997).

Similarly, an APV MPF-19 extruder exhibited higher values of Specific Mechanical Energy than the MPF-50 extruder under equivalent conditions (Singh *et al*., 1998). The transformation of cereal products on two extruders of different sizes is summarized in **Table 9**.

Table 9: The transformation of cereal products on two extruders of different sizes

Extruder type	Specific Power requirement	Product solubility	Starch transformation	Reference
(Raw material: Wheat flour)				Barres *et al*., 1990
Clextral BC 45[a], twin screw	higher	higher	ND	
Clextral BC 72[b], twin screw	lower	lower	ND	
(Raw material: Maize grits)				Cairns *et al*., 1997
APV Baker, MPF-19/25[c], twin screw	higher	ND	Fully gelatinised	
APV Baker, MPF-50/25[d] twin screw	lower	ND	partially gelatinised	
(Raw material: Wheat starch)				Singh *et al*.,1998
APV Baker, MPF-19/25[e] twin screw	higher	ND	more amylose gelatinised, more amylose-lipid formed and crystallised, higher crystallinity,	
APV Baker, MPF-50/25[f] twin screw	lower	ND	less amylose gelatinised, less amylose-lipid formed and less crystallised,lower crystallinity	

a 1 reverse screw/8mm, 150 rpm, 10kg/h or 2 reverse screw/8mm, 200 rpm, 30kg/h
b 1 reverse screw/8mm, 80 rpm, 120kg/h or 2 reverse screw/8mm, 80 rpm, 120kg/h
c 165°C/450 rpm, 10kg/h
d 165°C/450 rpm, 182kg/h
e 125°C/300 rpm, 2.6kg/h
f 125°C/300 rpm, 40kg/h

ND not detected

9. Summary

The physical and chemical properties of cereal extrudates depend on the wheat characteristics, location, milling size and storage conditions. The main variation in wheat variety is hardness or softness of grain (protein type); protein, amylose and fat content and geographical location of the crop. If the protein content is similar, hard wheat creates a more severe processing environment, causing higher heat and shear inputs, than soft wheat. It also ends to expand more with large cells. Hard wheat with high protein requires even more energy and produce rough cell walls. The expansion ratio generally increases with increasing amylose content. The presence of fat in cereal normally reduces the power requirement and expansion. Milling size is also one of the important factors in expanded wheat products. The optimum particle size to produce a product of general acceptance is between 120-150μm. The extrudate properties are unaffected if the storage temperature of the flour is -11°C. Ambient storage conditions tend to produce slimmer extrudates with higher pore density. It appears that larger extruders need less energy to produce similar products in both wheat and maize under equivalent conditions. In addition, the differences in physical and chemical properties of extrudates are more pronounced if severe extruder conditions, such as low moisture and high screw speeds are used.

From this literature survey, it can be concluded that the quality of wheat based extruded snacks are affected by (in the descending order):

- protein content
- wheat texture (hard or soft)
- particle size
- fat (added)
- geographic location
- amylose content
- storage conditions and
- type of extruder

10. Recommendations

The following factors should be considered when developing wheat based extruded snacks:

1. High protein hard wheat is not a favourable raw material.

2. Low protein hard wheat could be a possible ingredient.

3. Storage of milled flour is not recommended. Grain should be stored rather than flour for the consistency of product quality.

4. Rye and maize are suitable ingredients for product quality improvement.

5. As minor ingredients palm, coconut, peanut and wheat germ oils will enhance expansion and texture of the product.

6. High shear screw configuration is required for large scale production of snacks.

.11. Reference

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APPENDIX 5

Preliminary Study on the Effect of Flour Type on the Extrusion Characteristics of Wheats

Protocol No: CW001

Protocol No: CW001 Preliminary study on the effect of flour type on the extrusion characteristics of wheats.

Title Ref: c:\wheat crc\Protocol\CW001.doc

Background

Literature stated that the physical and chemical properties of cereal extrudates depend on the difference in variety, location, milling size and storage condition. In addition, grain hardness, protein, fat and amylose content was also related to the product characteristics. A preliminary trial should be undertaken to investigate the order of importance of these factors on product characteristics.

Aim

To investigate the effect of flour type on the extrusion behaviour and product quality between the hard and soft wheat.

Experimental Plan

Materials
Low protein wheat flour, Debranning Soft, E4061
High protein hard wheat flour, Bakers grist, low grind, E4062
High protein hard wheat flour, Bakers grist, high grind, E4063
(approx 80 Kg of each flour required)

Methods
Extrusion configuration
Long barrel, low shear, screw configuration No.15

Experimental design
Processing conditions
Moisture (22-17%), barrel temperature (150°C) and feed rate (30kg/h).
Vary screw speed (two levels 275 and 400 rpm)

1 kg product collections for each raw material and processing condition (ie 12 collections). Product placed in dehydrator (52°C) for drying immediately.

Measurements
Bulk density
Specific volume
Radial expansion
RVA

A method was developed to measure the pasting properties of extrudate by the Rapid Viscoanalyser (Model 4, Newport Scientific). Dried extrudates were chilled in dry ice for 10 min prior to milling. Chilled extrudates were then milled through 0.2mm screen on Fritsch mill (model Pulverisette 14) and sieved through 250µm sieve. The net starch weight of 3.5±0.01g (corrected for moisture and protein content) was accurately weighed into a screw

capped tube and added 1g 95% ethanol. Ethanol was worked into sample using a spatula to form a moist crumb. Water was added to a total weight of 35.0±0.1g (to give 10% w/w paste) and shook 30 min on a flask shaker at 700 oscillation per minute. The paste was stood at room temperature for another 30 min. A weight of 25±0.1g paste was quantitatively transferred to a RVA canister, held at 25°C for 2 min., heated from 25°C to 95°C in 4 min., kept at this temperature for 4 min., then cooled to 25°C in 4 min., and hold at 25°C for 6 min.
Log all processing data on Citect

Date started : 11/10/97

Date completed : 19/10/97

1 day for extruder run
5 days measurements, all data including process data on disc

Results

Discussion

Conclusion

- Specific Mechanical Energy

  Hard wheat required the highest energy to produce expanded product. Both differences in the level of grind and hardness were of small magnitude, and considerably influenced by the processing conditions.

  Hard wheat (low grind) > Hard wheat (high grind) > Soft wheat

- Expansion

  Generally, the expansion of 3 wheat flour extrudates under low moisture and medium or high shear operating conditions, follows this trend:

  Hard wheat (low grind) > Hard wheat (high grind) > Soft wheat

  Under higher moisture and medium or high shear operating conditions the difference in expansion of 3 wheat flour extrudates is not significant.

- Viscosity

  Peak viscosities of hard wheat (low and high grind) are significantly lower than soft wheat in most expanded product (low moisture and high shear) but not significant on other 3 conditions.

References

Report

Future work

Table 2: Extruder conditions and physical properties of three Wheat Expanded Products

Physical Property	Extruder Conditions			Wheat Flour extrudate		
	Moist (%)	Temp (°C)	Screw speed (RPM)	SW	HW(LG)	HW(HG)
SME (kJ/kg)	22	150	275	415.8	480.5	462.0
	22	160	400	483.8	537.6	537.6
	17	162	275	554.4	563.6	554.4
	17	170	400	591.4	618.2	604.8
Die Press (psi)	22	150	275	870	900	920
	22	160	400	580	510	510
	17	162	275	1120	1050	1030
	17	170	400	650	630	610
Motor Torque (%)	22	150	275	45	52	50
	22	160	400	36	40	40
	17	162	275	60	61	60
	17	170	400	44	46	45
Bulk Density (g/cm^3)	22	150	275	0.1335±0.0008	0.1307±0.0005	0.1386±0.0003
	22	160	400	0.1168±0.0003	0.1084±0.0001	0.1154±0.0005
	17	162	275	0.0590±0.0002	0.0507±0.0002	0.0532±0.0005
	17	170	400	0.0426±0.0001	0.0362±0.0003	0.0370±0.0002
Specific Volume (ml/g)	22	150	275	4.81±0.02	4.90±0.03	4.60±0.02
	22	160	400	5.35±0.02	5.52±0.01	5.37±0.02
	17	162	275	10.86±0.06	12.60±0.04	11.90±0.04
	17	170	400	14.81±0.08	17.23±0.01	17.08±0.06
Radial expansion index	22	150	275	3.59±0.09	3.49±0.11	3.45±0.17
	22	160	400	2.78±0.08	2.74±0.09	2.59±0.08
	17	162	275	4.16±0.11	4.37±0.07	4.31±0.12
	17	170	400	4.28±0.09	4.32±0.07	4.30±0.11
Peak Viscosity (RVU)	22	150	275	94.33	96.42	85.33
	22	160	400	78.50	75.92	66.00
	17	162	275	60.00	63.67	53.58
	17	170	400	69.00	44.75	46.58
Trough (RVU)	22	150	275	13.92	11.92	13.92
	22	160	400	8.25	8.75	10.42
	17	162	275	8.08	9.5	9.58
	17	170	400	9.42	7.08	9.08
Final Viscosity (RVU)	22	150	275	38.42	38.42	38.50
	22	160	400	26.75	28.58	29.92
	17	162	275	29.67	35.17	31.75
	17	170	400	35.50	28.08	31.50

APPENDIX 6

A Comparison of the Extrusion Behaviour of Three Wheats

Protocol No: CW002

Protocol No: CW002 "A comparison of the extrusion behaviour of three wheats

Title Ref: c:\wheat crc\Protocol\CW002.doc

Background

In an earlier preliminary trial (CW001) the effect of level of grind and grain hardness on the extrusion characteristics of wheat was examined. A limited number of responses were measured. These were specific mechanical energy, bulk density, specific volume and radial expansion. In general hard wheats took more energy to process for small increases in expansion. Both differences in the level of grind and hardness were of small magnitude, and considerably influenced by the processing conditions.

To further investigate the effect of hardness on the extrusion properties of wheats, two commercial flours were chosen, representing the extreme range for this grain characteristic and compared to a low protein hard wheat.

Aim

To characterise the differences in extrusion behaviour and product quality between three Australian wheat types.

Experimental Plan

Materials
Wheat flour

1. HYPRO flour, High protein flour (Ingredients: flour, Vitamin, Thiamin), hard wheat, 15 April 98, 00718, 90kg, Sr No: 164
2. SOFT flour, low protein, hard wheat, 8 April 98, 02398, 90kg, Sr No: 165
3. SOFYT BISCUIT, low protein, soft wheat,8 April 98, 02240, 90kg, Sr No: 166

Methods
<u>Extrusion configuration</u>
Short barrel 15D, medium shear screw configuration (No 23).

Experimental design
A short barrel configuration was used with a screw arrangement which produced a melt in the final barrel zone adjacent to the die. Barrel temperature settings were kept the same for all trials, to investigate frictional differences between the wheat flours that could be observed from differences in temperature of the barrel melts. Barrel moisture (four levels, 16%, 18%, 20% and 22%) and screw speed (two levels 275 and 350 rpm) were the processing conditions which were varied to differentiate the extrusion behaviour of the wheats. The responses measured were die pressure, melt temperatures, torque, specific mechanical energy, specific volume, radial and longitudinal expansion index, pasting viscosities (RVA), pore dimensions and texture (hardness and mechanical strength, using a penetration test).

Results

Some of the properties of the three wheats used in the extrusion trials are given in **Table 1**.

Table 1: Properties of wheats

Wheat variety	Protein (N x 5.7) %	Falling No. (sec)	Water Absorption %	Particle size < 40μm %	RVA, Final Viscosity (RVU)
LOPRO Soft	7.9	363	59.6	43	427
LOWPRO Hard	8.6	514	58.9	33	419
HYPRO Hard	12.9	660	65.9	22	344

Although differences were observed in the processing characteristics between the three wheats, overall the magnitude of the differences was not great.

Melt temperatures in the shear zone (Zone 9, **Figures 1 and 2**) were always highest for the high protein hard wheat, which were always higher than values for soft wheat. This result indicated that the high protein hard wheat generated more heat from frictional resistance in the barrel, than the other wheats. This could arise from a number of factors, such as starch granule/protein body melting temperature and structural characteristics, melt viscosities and hydration rates. This trial was however planned to establish in the first instance the presence and magnitude of differences, rather than their cause.

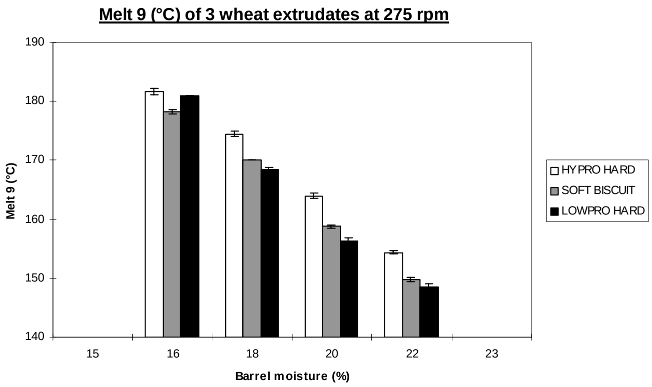


Figure 1: Melt temperatures in barrel zone 9 at screw speed 275 rpm. Vertical bars are ± 1 SD

At moistures of 22% to 18% the low protein hard wheat generated less heat than the soft wheat, although at 16% moisture this response was reversed.

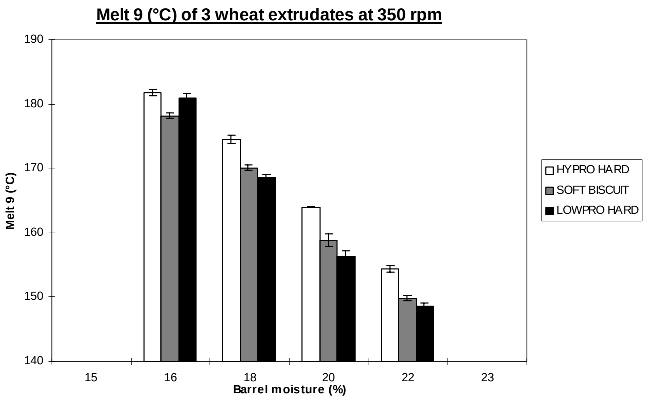


Figure 2: Melt temperatures in barrel zone 9 at screw speed 350 rpm

The energy required to extrude the wheats, measured as specific mechanical energy, was greatest under all processing conditions for the high protein hard wheat, and generally least for the low protein hard wheat (Figures 3 and 4). As would be expected, similar trends were observed for specific mechanical energy and the temperature of the shear zone. The magnitude of the differences appeared to be more influenced by screw speed than barrel moisture.

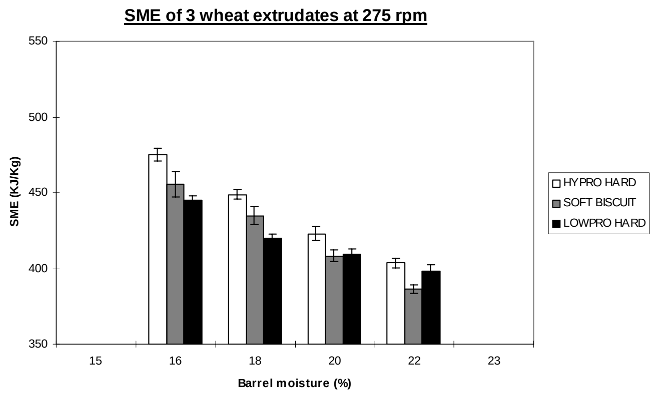


Figure 3: Specific mechanical energy for extrusion of wheat flours at 275 rpm

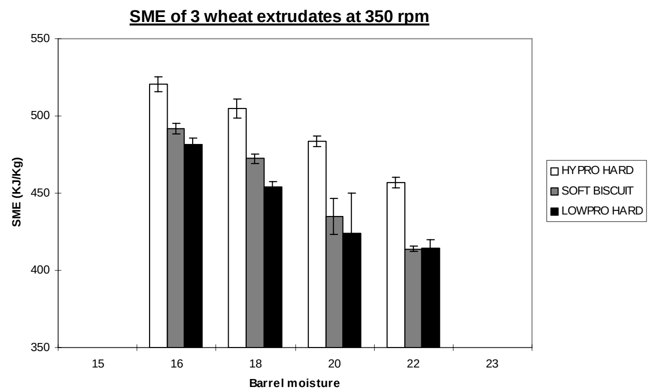


Figure 4: Specific mechanical energy for extrusion of wheat flours at 350 rpm

The level of expansion of extruded wheats, measured as specific volume is shown in **Figures 5 and 6**. Both barrel moisture and screw speed had major effects on the specific volume of extrudates from all wheats. Ranking of the differences between the wheats was also affected by both processing variables. However under the lowest barrel moisture conditions, the low protein hard wheat showed the greatest expansion with the lowest level of energy input (**Figures 3 and 4**).

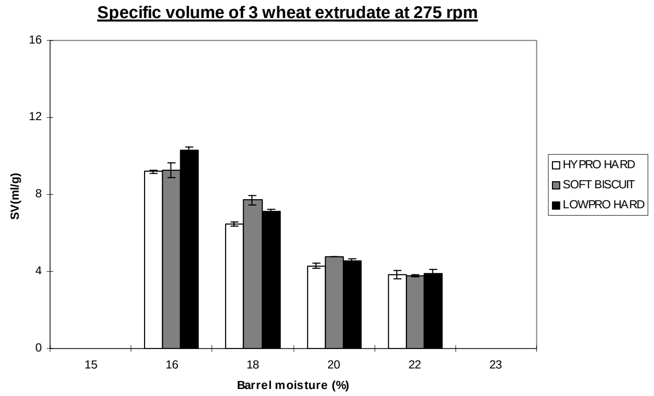


Figure 5: Specific volume of extruded wheat flours at 275 rpm

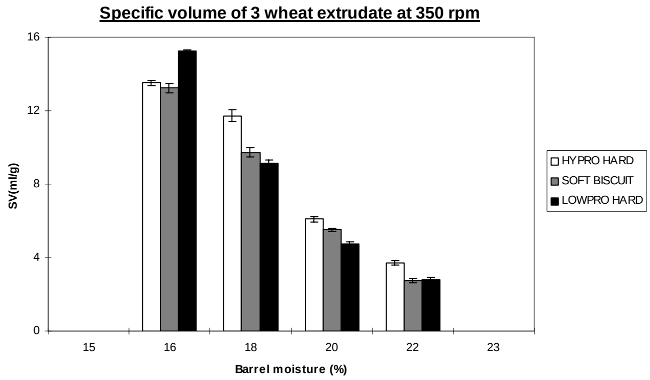


Figure 6: Specific volume of extruded wheat flours at 350 rpm

Barrel moisture normally has a major influence on extrudate hardness, largely associated with the degree of expansion. Differences between the wheats in hardness (texture) at low moistures, were small and unlikely to be significant (**Figures 7 and 8**).

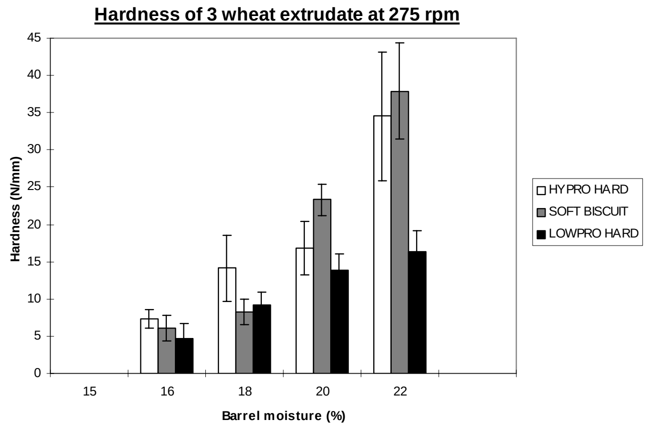


Figure 7: Hardness of extruded wheat flours at 275 rpm

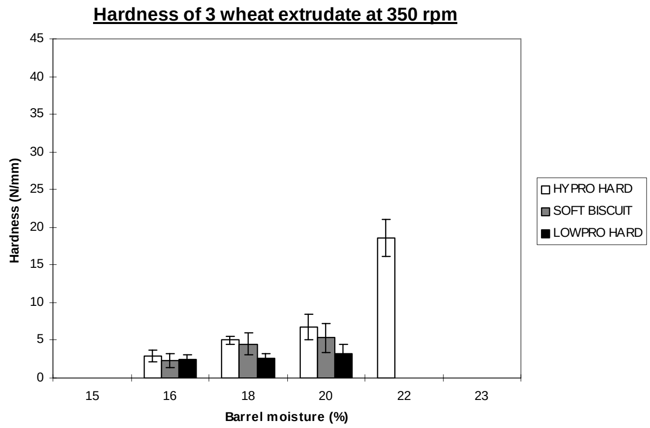


Figure 8: Hardness of extruded wheat flours at 350 rpm

Concluding Remarks

This report provides some preliminary results from the second extrusion trial. Only a selection of the data has been included. Since this work was completed, additional comparative extrusion trials have been undertaken using another cereal. Analysis of this material is almost complete, but has delayed the analysis of the whole data set.

The overview provided from the results for the three wheat flours, is that there are no advantages to be gained by using a high protein hard wheat in extrusion food applications, where the desirable characteristics for a raw material are the production of good expansion and texture with the lowest energy input. In general the protein in wheat tends to reduce expansion. In these trials, the low protein hard wheat performed well, and may be worth considering further. However although differences between the three wheat types were frequently of a statistical significance, they were often of relatively small magnitude. The importance of these differences therefore in a commercial operation is uncertain, and further trials should be undertaken to unambiguously determine the order of importance of these grain differences.

APPENDIX 7

A Comparison of the Extrusion Behaviour of Three Wheat Varieties under High Shear and Adiabatic Conditions

Protocol No: CW003

Protocol No: CW003 A comparison of the extrusion behaviour of three wheat varieties under high shear and adiabatic conditions.

File Ref: c:\WheatCRC\Protocol\CW003.doc

Background

In the previous trials (CW002), a comparison was made between the extrusion properties of three wheat flours and one rice flour. Although the magnitude of the differences between the wheat flours was relatively small, it was consistently demonstrated from that trial that the flour from the low protein hard wheat performed better than the other two wheat flours. As this was an observation of considerable interest, it was considered important to repeat the comparative trials under conditions closer to those used in industry for the production of expanded foods.

For these experimental trials, a twin screw and single extruder will be used, both operating under adiabatic conditions, and using processing settings as recommended by industry users. The purpose of these trials is therefore to validate the previous observations under more normal commercial operating conditions. In all cases wheat flours without additions will be used.

Aim

To compare the extrusion properties of three wheat flours under adiabatic conditions in a twin screw extruder.

Experimental Plan

Extruder
twin screw APV Baker MPF40,

Materials
High protein hard wheat, HYPRO flour, Sr. No. 185 (8/9/98)
Low protein hard wheat, SOFT flour, Sr. No. 184 (8/9/98)
Low protein soft , SOFT BISCUIT, Sr. No. 183 (8/9/98)
Waratah Mill, Summer Hill

Methods
Experimental design
3 Wheat flours, and 3 barrel moistures and one screw speed

<u>Twin screw extrusion.</u>
Extrusion configuration
Short barrel (15D), high shear screw configuration (No 29)
4D FS, 8x30° FP, 4D SLS, 2x90° FP, 7x30° RP, 1 SDS (Die end)

<u>Extrusion Conditions</u>
(Barrel Temperature 150 deg C at start up only, thereafter adiabatic)
Feed Rate 30 kg/h
Die one 4mm diam, land length, 12.6 mm (die conductance, k = 0.5)

Die Press within range 700-1,100 psi
Cutter 2 blade

Processing Variables
Barrel moisture 16, 18, 20%

Screw Speed and feed rate will be determined in a preliminary trial. It is likely that if we maximise feed rate (flow rate through the die) we will only use one screw speed for the trial (325 rpm). Using the suggested die conductance and flow rate, and feeding wheat flour alone, we will have to ensure that the extrudate is not overcooked by these conditions, as previous trials would indicate that we will need to shear the material considerably to control die pressure.

Sample Collections
Duplicate 1 kg samples collected for each run condition (6 samples/wheat) and placed directly in dehydrator (50 deg C overnight) for drying.
Samples collected from each screw section for dead stop. Initially kept at 4 deg C.

Measurements
Raw materials characterisation
Grain Hardness
Starch Damage
Starch Characteristics
Particle size
Water absorption/RVA
Gluten content and strength
Composition

Processing Responses (logged with Citect)
Die pressure
Melt temperatures
Torque
SME

Extrudate Properties (measurements on duplicate sample collections)
Radial expansion
Specific volume
Pasting curves (RVA)
Sensory attributes to be performed by Uncle Tobys Sensory Panel
Texture

Dead Stop samples
Microscopy

Date started	**Date completed**
9/9/98	8/10/98

Results

Melt Temperature of the final barrel zone adjacent to the die

The trial (CW003) of three wheat flours was made on a twin screw extruder, operating under adiabatic conditions, and using processing settings as recommended by industry users. Some differences were observed in the processing responses between the three wheats. Overall, the magnitude of the differences was slighter greater than in the previous trial (CW002).

Melt temperatures in the shear zone (Zone 9, Figure 1) were always highest for the high protein hard wheat, which were always significantly higher than values for soft wheat and low protein hard wheat at all moistures. The same order of the melt temperatures of the three wheats follows consistently at all moistures, which was not observed in the previous trial (CW002). The cause of generation of more heat from high protein hard wheat could arise from friction between harder granules. In addition, more interactions between protein and starch granules could occur (**Table 1**).

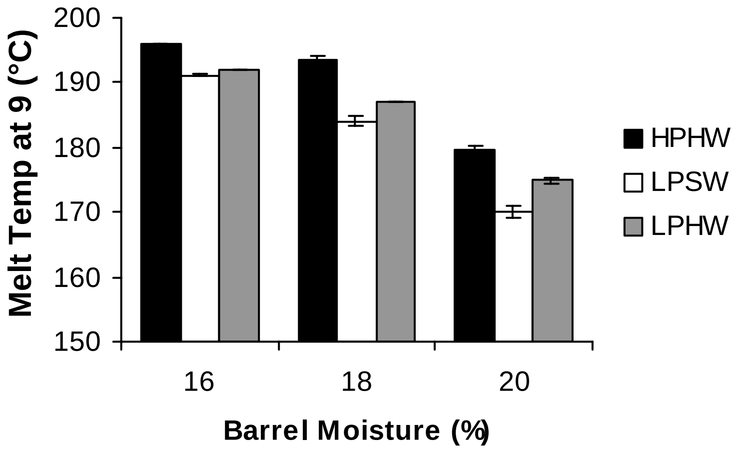


Figure 1: Melt temperatures in barrel zone 9 at screw speed 325 rpm. Vertical bars are ± 1 SD

Table 1: Properties of wheat varieties

Wheat variety	Protein (N x 5.7) (%)	Wheat hardness (PSI)	Water absorption (%)	Particle size <40μm %
Low protein soft wheat	7.9	14.5	59.6	43
Low protein hard wheat	8.6	17.5	58.9	33
High protein hard wheat	12.9	22.5	65.9	22

PSI Particle size index

Die melt temperature

The die melt temperatures of the three wheats showed exactly the same trend as the zone 9 melt temperature trend (Figure 2). However, at the moisture content of 18% and 16% the low protein hard wheat generated slightly higher die melt temperatures than high protein hard wheat in the previous trial (CW002). Adiabatic and high shear processing conditions generates consistent results and trends than in the non-adiabatic run.

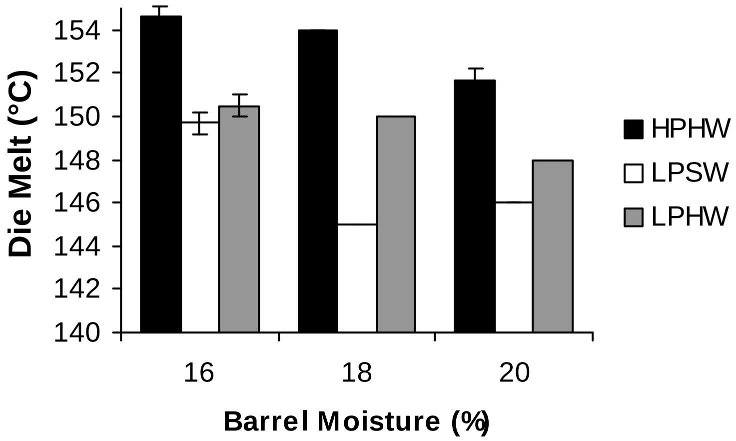


Figure 2: **Die melt temperatures at a screw speed of 325 rpm. Vertical bars are ± 0.5 SD**

Specific Mechanical Energy (SME)

The specific mechanical energy was highest for all moisture contents for the high protein hard wheat, and generally lowest for the low protein hard wheat (**Figure 3).** Although differences in ranking of the three wheats were observed in the melt temperature at barrel zone 9 and die trends in the two trials (CW002 and CW003) at 18% and 20% moistures, the resultant SME trends were identical. The magnitude of the differences in SME between the three varieties of wheat in this trial appeared to be less than the previous trial. However, low protein hard wheat required the least amount of energy to produce expanded product.

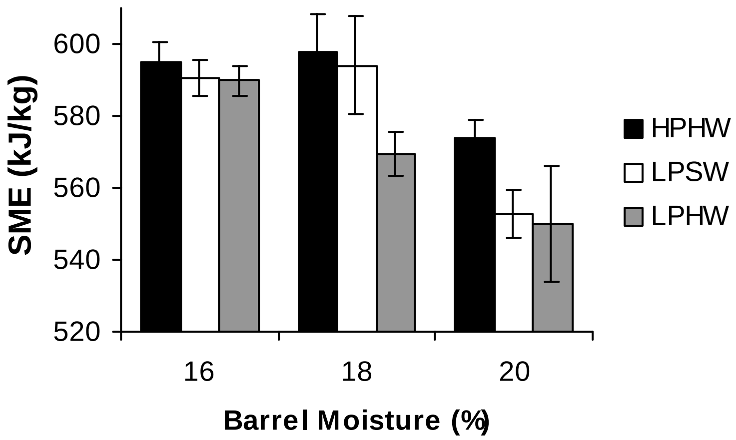


Figure 3: **Specific mechanical energy (SME) for extrusion of three wheat flours at a screw speed 325 rpm. Vertical bars are ± 15 SD**

Under high shear and adiabatic conditions, the SME values of the three wheat varieties were significantly higher than the previous trial (non-adiabatic and medium shear conditions, CW02). This was attributed to the addition of more reverse paddles, which increased melt length in the CW03 trial. At the same time the die opening was reduced from 5 to 4mm and the die conductance was reduced from 7.7 to 0.5. All these changes add up more load on the motor. Secondly, to extrude powdered raw materials through the small opening, starch has to be melted. In the non-adiabatic trial, the friction heat and the external heat applied have assisted starch melt. In the adiabatic trial starch melt was solely from friction heat.

Die Pressure

The die pressures of the three types of wheats were highest for the low protein soft wheat, which were always higher than values for high protein hard wheat (Figure 4). This observation was the reverse of the previous trial findings. In the case of high protein hard

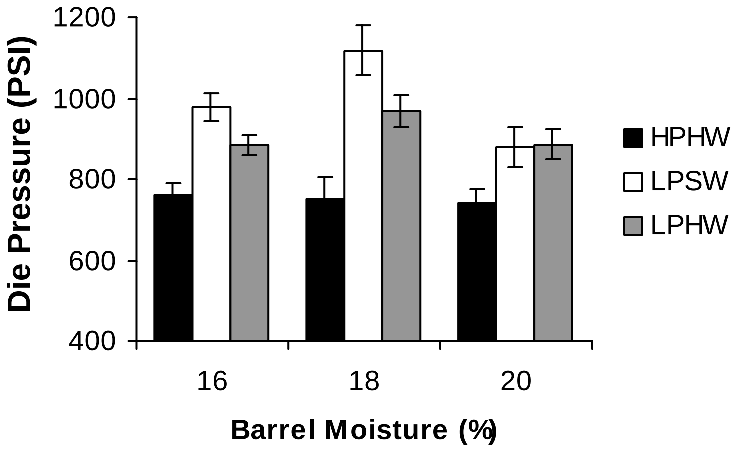


Figure 4: Die pressure of three wheat flours extruded at a screw speed of 325 rpm. Vertical bars are ± 60 SD.

wheat, the hard grains produce more damage starches in milling. These types of starches tend to absorb more water (**Table 1**). The high water absorption weakens starch structure and increases gelatinisation in the extruder These conditions create increased swelling of starch granules and reduced melting of starch which gives a low melt viscosity resulting in a low die pressure. Generally, the low initial viscosity of high protein hard wheat extrudate in RVA pasting curve reflects this phenomena (**Figure 5**). As would be expected, in the case of low protein soft wheat, increased melting is attributed to the higher concentration of smaller granular particles and lower water absorption leading to high die pressure.

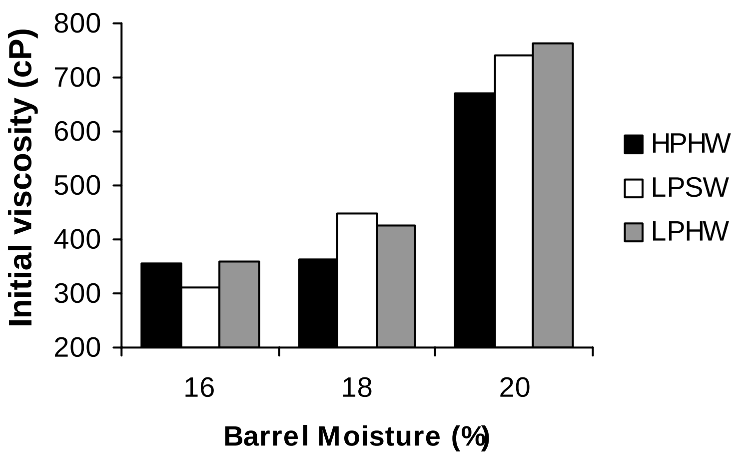


Figure 5: Initial viscosity of three wheat flours extruded at a screw speed of 325 rpm

Expansion

The level of expansion of the three extruded wheat varieties depends on a number of factors. The overall expansion, measured as specific volume is mainly influenced by the barrel moisture content, the melt temperature at the die and the melt viscosity (Note: Die diameter and land length of CW003 trial was 4mm and 12.6mm, respectively, compared to 5mm and 2mm, respectively in CW002 trial).

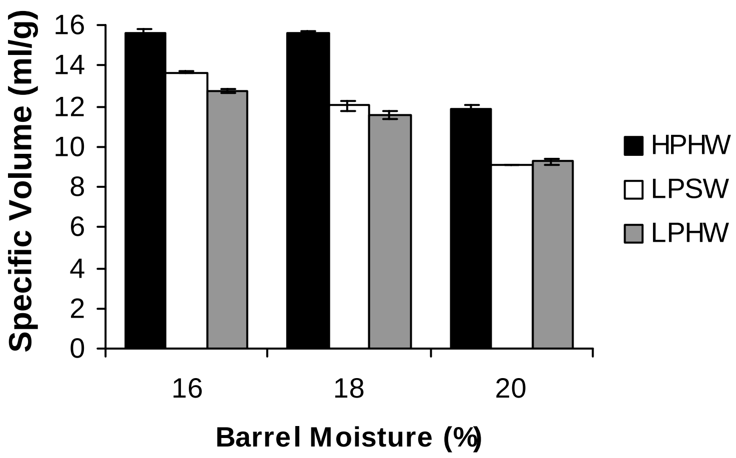


Figure 6: Specific volume of extruded wheat flour at 325 rpm. Vertical bars are ± 0.25 SD

As would be expected, similar trends were observed for specific volume of the three wheat varieties (**Figure 6**) and the die melt temperature (**Figure 2**). Adiabatic and high shear extruder conditions have reversed the expansion trends of the previous trial. The overall expansion (specific volume) is mainly controlled from the longitudinal expansion. It can be seen from **Figure 7** and **Figure 8** that the longitudinal expansion appeared to be extensively favoured by longer land length and lower melt viscosity, which in turn was the result of increased melt temperatures. There is generally a negative correlation between longitudinal and radial expansion.

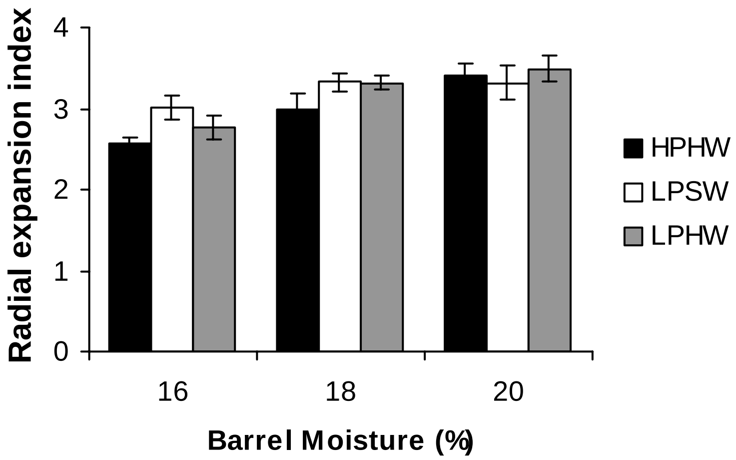


Figure 7: Radial expansion index of extruded flour at 325 rpm. Vertical bars are ± 0.20 SD

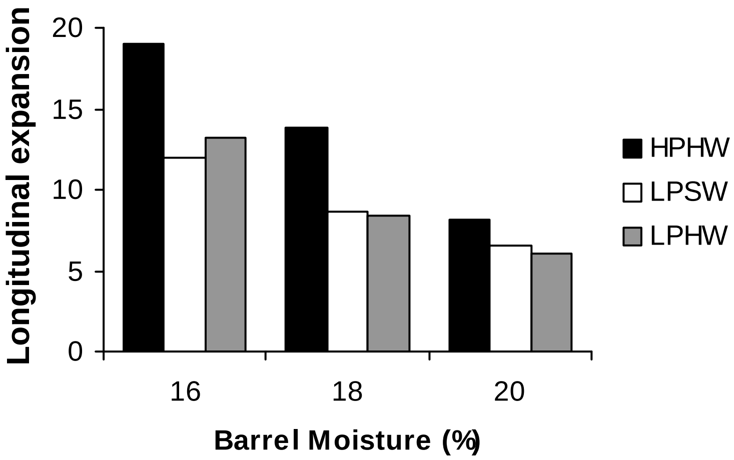


Figure 8: **Longitudinal expansion of extruded wheat flours at 325 rpm**

Hardness of the extrudate

The barrel moisture content normally has a major influence on the extrudate hardness, largely associated with the degree of expansion. The differences between the wheats in hardness at lower moistures, were consistently small at 16 and 18% moistures (**Figure 9**).

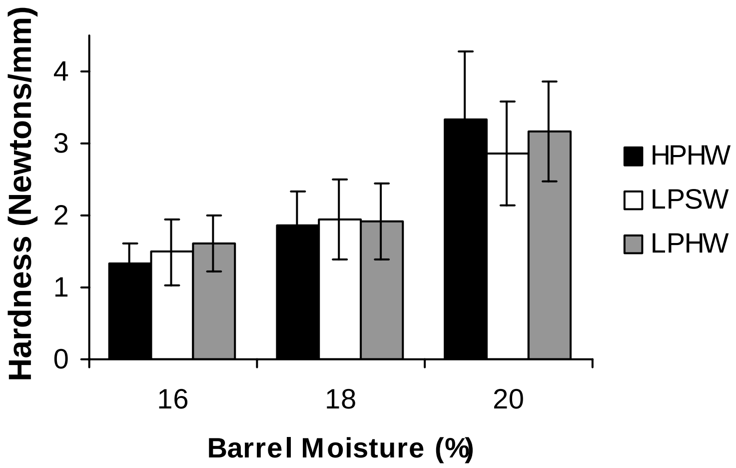


Figure 9: **Hardness of extruded wheat flours at 325 rpm. Vertical bars are ± 0.95 SD**

Conclusions

The results from this trial show that the product characteristic of high protein hard wheat is different to low protein hard wheat and soft wheat when extruded under high shear and adiabatic conditions. This is probably because of the different particle sizes (because of the effect of grain hardness on milling), starch-protein interactions and water absorption capacity of flours from different wheat varieties.

The main conclusions from this trial can be summarised as follows:

2. The differences in the product characteristics using three varieties of wheat are slightly greater when the extruder is operated under adiabatic conditions (when compared to operating with the addition of external heat).

3. There are no significant differences in product characteristics of low protein hard and soft wheat extruded at low moisture contents (16 and 18%).

4. The grain hardness (which affects the particle size distribution in milling), appears to be an important factors in affecting the product characteristics.

5. Low protein hard wheat requires the lowest amount of energy to produce expanded products. The degree of expansion and texture of the product for low protein hard wheat could be improved by adding external heat during extrusion cooking.

6. Low protein hard wheat had significantly stronger puffed wheat aroma and overall flavour, more tooth packing, faster rate of disappearance, more mouth-drying and more sticking to teeth than low protein soft wheat.

7. High protein hard wheat variety was also significantly stronger puffed wheat aroma, overall aroma and aftertaste smoked flavour compared to low protein hard and soft wheats.

References

Future work

1. It may be worth considering further trials in attempting to produce expanded products from low protein hard wheat under high shear and the addition of external heat. It may be interesting to know the changes in expansion and SME of the low protein hard wheat if the external heat applied is high enough to raise die melt temperature to the temperature achieved by high protein hard wheat extrudate. [The decision made on the (23/10 98) meeting was that further twin screw extrusion work would be postponed until the sensory results are analysed and the single screw trials have been performed.]

2. Plan single screw extrusion trials.

EXPERT SENSORY PANEL EVALUATION

PROJECT WHEAT – CRC

16% Barrel Moisture & 325 rpm Screw Speed

REF: SE0546

REQUESTED BY: S WESTCOTT
CC: J WELLER, D MISKELLY
TEST DATE: 10/11/98
ISSUE DATE: 27/11/98

BACKGROUND

The aim of this project is to determine if the performance of varying wheat varieties in both processing and consumption is independent of their properties.

Each sample has been run on a twin screw extruder operating under adiabatic conditions and dried at 6% moisture.

AIM

The aim of this evaluation is to determine if there are any significant differences between the High Protein Hard Wheat sample, the Low Protein Soft Wheat sample and the Low Protein Hard Wheat sample processed at 16% Barrel Moisture.

METHOD OF SENSORY ASSESSMENT

The panelists evaluated three samples of Wheat Puffs, evaluated dry only.

Mean Sensory Scores were calculated for each sample according to attributes determined by the Trained Panels in a round table discussion.

Attributes were scored on a line scale of 0 - 100mm. The anchor points for each attribute are listed in **Table 1**.

COMPARISON OF SAMPLES

099 Sample # 1327, Low protein soft wheat }
462 Sample # 1328, High protein hard wheat }16% Barrel moisture & 325 rpm Screw speed
833 Sample # 1331, Low protein hard wheat }

These samples were evaluated with respect to each attribute and the results are summarised in **Table 2**.

COMMENTS

The Low Protein Soft Wheat (1327) sample was perceived as being significantly:
- more Mouthdrying

than the High Protein Hard Wheat (1328) sample.

The Low Protein Soft Wheat (1327) sample was perceived as being significantly:
- darker in Colour
- weaker in Puffed Wheat aroma
- weaker in Overall flavour
- slower in Rate of Disappearance and Sticking to teeth less

than the Low Protein Hard Wheat (1331) sample.

The High Protein Hard Wheat (1328) sample was perceived as being significantly;
- darker in Colour
- weaker in Puffed Wheat aroma
- weaker in Overall flavour
- slower in Rate of Disappearance
- less Mouthdrying and Sticking to Teeth less

than the Low Protein Hard Wheat (1331) sample.

C MARTIN
SENSORY TECHNICIAN

S M ALEXANDER
SENSORY CO-ORDINATOR

Comments by individual panelists:

1327 – Low protein soft wheat
- Soft and slimy in mouth
- Slimy feeling when soft (in mouth)
- White sections on the surface
- Goes slimy before disappearing

1331 – Low protein hard wheat
- No comments

1328 – High protein hard wheat
- Low salt flavour detected

TABLE 1

ATTRIBUTES AND ANCHOR POINTS

	ATTRIBUTES	ANCHOR POINTS	
Appearance	Colour	White	Light Brown
	Air Bubbles	Uneven	Even
	Air Bubbles	Small	Large
Aroma	Overall	Weak	Strong
	Puffed Wheat	Weak	Strong
	Dusty	Weak	Strong
Flavour	Overall	Weak	Strong
	Puffed Wheat	Weak	Strong
	Smoked	Weak	Strong
	Aftertaste, Smoked	Weak	Strong
Texture	Sticks to Teeth	Not Much	Much
	Rate of Disappearance	Slow	Fast
	Mouthcoating	Not Much	Much
	Crisp	Not Very	Very
	Toothpacking	Not Very	Very
	Mouthdrying	Not Very	Very

TABLE 2

MEAN SENSORY VALUES FOR

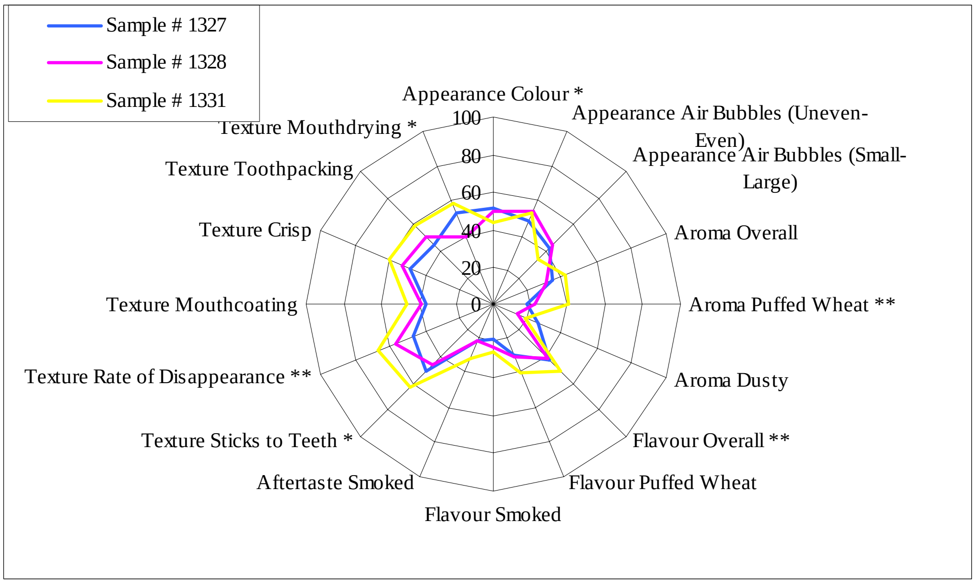
099 Sample # 1327 Low Protein Soft Wheat
462 Sample # 1328 High Protein Hard Wheat
833 Sample # 1331 Low Protein Hard Wheat

ATTRIBUTES	099	462	833	SIGNIFICANCE	p-VALUE
Appearance:					
Colour	51.6	49.7	43.4	*	0.046
Air Bubbles	49.1	54.1	52.6	NS	0.678
Air Bubbles	43.1	45.4	34.1	NS	0.199
Aroma:					
Overall	34.3	30.4	41.9	NS	0.192
Puffed Wheat	17.9	22.3	40.6	**	0.006
Dusty	25.9	14.0	19.1	NS	0.113
Flavour:					
Overall	41.9	41.0	50.4	**	0.009
Puffed Wheat	29.6	30.9	39.4	NS	0.125
Smoked	18.6	22.9	25.4	NS	0.399
Aftertaste, Smoked	21.7	21.4	31.7	NS	0.102
Texture:					
Sticks to Teeth	48.0	46.6	63.6	*	0.031
Rate of Disappearance	46.3	56.4	66.4	**	0.008
Mouthcoating	35.9	38.4	46.0	NS	0.151
Crisp	47.6	53.0	61.0	NS	0.115
Toothpacking	45.0	50.6	59.7	NS	0.093
Mouthdrying	53.0	38.3	58.0	*	0.015

Significance levels:

p -Value:			
0.000 - 0.001	***	=	0.1% Significance Level
0.001 - 0.010	**	=	1% Significance Level
0.010 - 0.050	*	=	5% Significance Level
	NS	=	Not Significant

16% Barrel Moisture & 325 rpm Screw Speed



EXPERT SENSORY PANEL EVALUATION

PROJECT WHEAT - CRC

18% Barrel Moisture & 325 rpm Screw Speed

REF: SE0546A

REQUESTED BY: S WESTCOTT
CC: J WELLER, D MISKELLY
TEST DATE: 17/11/98
ISSUE DATE: 27/11/98

BACKGROUND

The aim of this project is determine if the performance of varying wheat varieties in both processing and consumption is independent of their properties.

Each sample has been run on a twin screw extruder operating under adiabatic conditions and dried at 6% moisture.

AIM

The aim of this evaluation is to determine if there are any significant differences between the High Protein Hard Wheat sample, the Low Protein Soft Wheat sample and the Low Protein Hard Wheat sample processed at 18% Barrel Moisture.

METHOD OF SENSORY ASSESSMENT

The panelists evaluated three samples of Wheat Puffs, evaluated dry only.

Mean Sensory Scores were calculated for each sample according to attributes determined by the Trained Panels in a round table discussion.

Attributes were scored on a line scale of 0 - 100mm. The anchor points for each attribute are listed in **Table 1**.

COMPARISON OF SAMPLES

011 Sample # 1326, Low protein soft wheat }
599 Sample # 1329, High protein hard wheat }18% Barrel moisture & 325 rpm Screw speed
218 Sample # 1332, Low protein hard wheat }

These samples were evaluated with respect to each attribute and the results are summarised in **Table 2**.

COMMENTS

The Low Protein Soft Wheat (1326) sample was perceived as being significantly;
- weaker in Overall, Puffed Wheat and Dusty aromas
- weaker Smoked aftertaste

than the High Protein Hard Wheat (1329) sample.

The Low Protein Soft Wheat (1326) sample was perceived as being significantly;
- weaker Overall and Dusty aromas

than the Low Protein Hard Wheat (1332) sample.

The High Protein Hard Wheat (1329) sample.was perceived as being significantly;
- stronger in Overall and Puffed Wheat aromas
- stronger in Smoked aftertaste
- more Toothpacking

than the Low Protein Hard Wheat (1332) sample.

C MARTIN
SENSORY TECHNICIAN

S M ALEXANDER
SENSORY CO-ORDINATOR

Comments by individual panelists:

<u>1326 – Low protein soft wheat</u>
- Cleaner flavour
- Rounded shape

<u>1329 – High protein hard wheat</u>
- Longer
- Chewy

<u>1332 – Low protein hard wheat</u>
- Shorter in size
- A little salty

TABLE 1

ATTRIBUTES AND ANCHOR POINTS

	ATTRIBUTES	ANCHOR POINTS	
Appearance	Colour	White	Light Brown
	Air Bubbles	Uneven	Even
	Air Bubbles	Small	Large
Aroma	Overall	Weak	Strong
	Puffed Wheat	Weak	Strong
	Dusty	Weak	Strong
Flavour	Overall	Weak	Strong
	Puffed Wheat	Weak	Strong
	Smoked	Weak	Strong
	Aftertaste, Smoked	Weak	Strong
Texture	Sticks to Teeth	Not Much	Much
	Rate of Disappearance	Slow	Fast
	Mouthcoating	Not Much	Much
	Crisp	Not Very	Very
	Toothpacking	Not Very	Very
	Mouthdrying	Not Very	Very

TABLE 2

MEAN SENSORY VALUES FOR

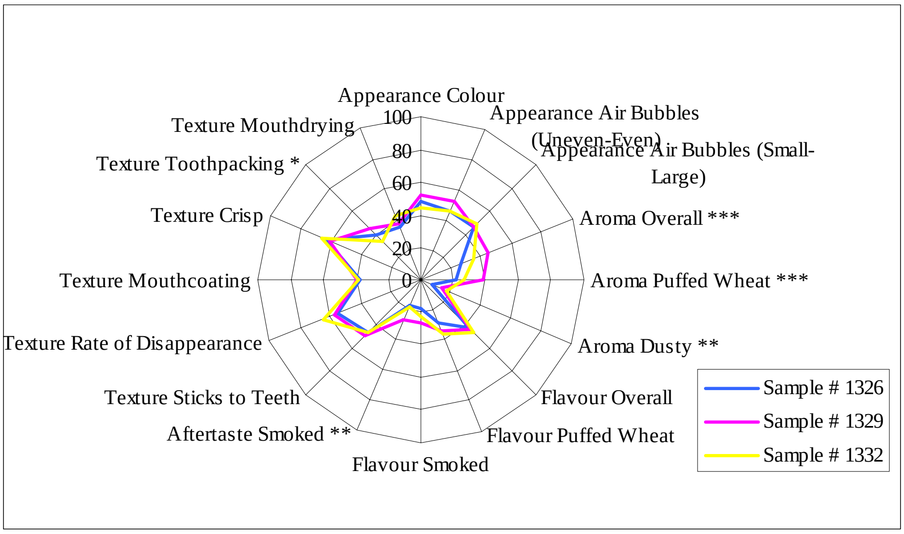
011 Sample # 1326 Low Protein Soft Wheat
599 Sample # 1329 High Protein Hard Wheat
218 Sample # 1332 Low Protein Hard Wheat

ATTRIBUTES	011	218	599	SIGNIFICANCE	p-VALUE
Appearance:					
Colour	48.3	44.4	52.4	NS	0.100
Air Bubbles	46.5	45.8	51.8	NS	0.497
Air Bubbles	44.8	49.5	46.4	NS	0.646
Aroma:					
Overall	26.8	35.6	44.5	***	0.001
Puffed Wheat	21.1	26.8	38.3	***	0.000
Dusty	7.6	16.8	13.4	**	0.003
Flavour:					
Overall	41.3	45.8	43.6	NS	0.349
Puffed Wheat	28.1	35.9	33.5	NS	0.143
Smoked	17.4	22.4	26.1	NS	0.133
Aftertaste, Smoked	17.1	18.3	26.4	**	0.008
Texture:					
Sticks to Teeth	44.8	45.6	48.1	NS	0.582
Rate of Disappearance	55.1	64.3	57.0	NS	0.191
Mouthcoating	37.3	37.8	39.6	NS	0.810
Crisp	63.0	66.1	61.0	NS	0.446
Toothpacking	37.8	33.8	47.0	*	0.046
Mouthdrying	34.9	42.6	37.5	NS	0.084

Significance levels:

p -Value:	0.000 - 0.001	***	=	0.1% Significance Level
	0.001 - 0.010	**	=	1% Significance Level
	0.010 - 0.050	*	=	5% Significance Level
		NS	=	Not Significant

18% Barrel Moisture & 325 rpm Screw Speed



EXPERT SENSORY PANEL EVALUATION

PROJECT WHEAT - CRC

20% Barrel Moisture & 325 rpm Screw Speed

REF:	SE0546B
REQUESTED BY:	S WESTCOTT
CC:	J WELLER, D MISKELLY
TEST DATE:	24/11/98
ISSUE DATE:	27/11/98

BACKGROUND

The aim of this project is determine if the performance of varying wheat varieties in both processing and consumption is independent of their properties.

Each sample has been run on a twin screw extruder operating under adiabatic conditions and dried at 6% moisture.

AIM

The aim of this evaluation is to determine if there are any significant differences between the High Protein Hard Wheat sample, the Low Protein Soft Wheat sample and the Low Protein Hard Wheat sample processed at 20% Barrel Moisture.

METHOD OF SENSORY ASSESSMENT

The panelists evaluated 3 samples of Wheat Puffs, evaluated dry only.

Mean Sensory Scores were calculated for each sample according to attributes determined by the Trained Panels in a round table discussion.

Attributes were scored on a line scale of 0 - 100mm. The anchor points for each attribute are listed in **Table 1**.

COMPARISON OF SAMPLES

076	Sample # 1325,	Low protein soft wheat	}
298	Sample # 1330,	High protein hard wheat	}20% Barrel moisture & 325 rpm Screw speed
441	Sample # 1333,	Low protein hard wheat	}

These samples were evaluated with respect to each attribute and the results are summarised in **Table 2.**

COMMENTS

The Low Protein Soft Wheat (1325) sample was perceived as being significantly;

- smaller Air Bubbles
- slower in Rate of Disappearance

than the High Protein Hard Wheat (1330) sample.

The Low Protein Soft Wheat (1325) sample was perceived as being significantly;

- less Toothpacking

than the Low Protein Hard Wheat (1333) sample.

The High Protein Hard Wheat (1330) sample was perceived as being significantly;

- larger Air Bubbles
- faster in Rate of Disappearance
- less Toothpacking

than the Low Protein Hard Wheat (1333) sample.

C MARTIN
SENSORY TECHNICIAN

S M ALEXANDER
SENSORY CO-ORDINATOR

Comments by individual panelists:

1325 – Low protein soft wheat

- Some pieces look burnt
- Some of light brown colour on sides
- Uneven in size, hard to break
- Small size
- Smaller
- Tasted salty

1333 – Low protein hard wheat

- Short and round in shape

1330 – High protein hard wheat

- Puffed wheat aftertaste
- Crunchy

TABLE 1

ATTRIBUTES AND ANCHOR POINTS

	ATTRIBUTES	ANCHOR POINTS	
Appearance	Colour	White	Light Brown
	Air Bubbles	Uneven	Even
	Air Bubbles	Small	Large
Aroma	Overall	Weak	Strong
	Puffed Wheat	Weak	Strong
	Dusty	Weak	Strong
Flavour	Overall	Weak	Strong
	Puffed Wheat	Weak	Strong
	Smoked	Weak	Strong
	Aftertaste, Smoked	Weak	Strong
Texture	Sticks to Teeth	Not Much	Much
	Rate of Disappearance	Slow	Fast
	Mouthcoating	Not Much	Much
	Crisp	Not Very	Very
	Toothpacking	Not Very	Very
	Mouthdrying	Not Very	Very

TABLE 2

MEAN SENSORY VALUES FOR

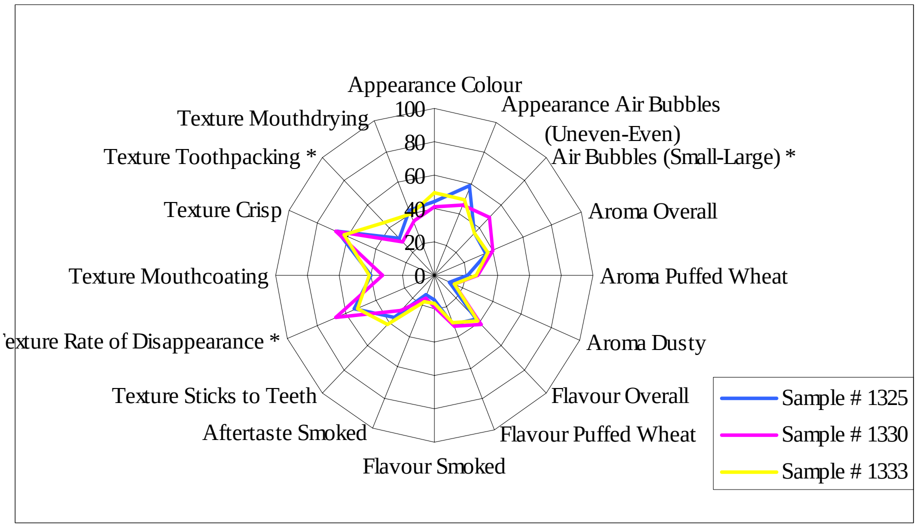
076 Sample # 1325 Low Protein Soft Wheat
298 Sample # 1330 High Protein Hard Wheat
441 Sample # 1333 Low Protein Hard Wheat

ATTRIBUTES	076	298	441	SIGNIFICANCE	p-VALUE
Appearance:					
Colour	44.6	40.8	49.1	NS	0.243
Air Bubbles	58.0	45.0	49.8	NS	0.129
Air Bubbles	35.5	48.8	35.4	*	0.032
Aroma:					
Overall	34.3	40.3	36.3	NS	0.502
Puffed Wheat	20.6	27.3	26.5	NS	0.174
Dusty	10.1	13.4	13.6	NS	0.375
Flavour:					
Overall	38.4	42.0	38.9	NS	0.688
Puffed Wheat	31.5	32.4	30.4	NS	0.798
Smoked	14.4	18.6	16.8	NS	0.486
Aftertaste, Smoked	12.8	15.0	17.3	NS	0.493
Texture:					
Sticks to Teeth	36.0	29.6	40.6	NS	0.341
Rate of Disappearance	54.6	67.4	53.0	*	0.015
Mouthcoating	39.9	32.5	41.5	NS	0.077
Crisp	66.4	67.6	62.4	NS	0.305
Toothpacking	31.5	28.0	43.9	*	0.011
Mouthdrying	41.9	35.3	40.0	NS	0.450

Significance levels:

p -Value:				
	0.000 - 0.001	***	=	0.1% Significance Level
	0.001 - 0.010	**	=	1% Significance Level
	0.010 - 0.050	*	=	5% Significance Level
		NS	=	Not Significant

20% Barrel Moisture & 325 rpm Screw Speed



EXPERT SENSORY PANEL EVALUATION

PROJECT WHEAT – CRC

Summary of Sensory Evaluations LOPRO Soft, LOPRO Hard and HYPRO Hard

REF:	SE0546Z
REQUESTED BY:	S WESTCOTT
CC:	J WELLER, D MISKELLY
ISSUE DATE:	27/11/98

BACKGROUND

The aim of this project is determine if the performance of varying wheat varieties in both processing and consumption is independent of their properties.
Each sample has been run on a twin screw extruder operating under adiabatic conditions and dried at 6% moisture.

AIM

The aim of this evaluation is to provide a summary of results obtained from Sensory Evaluations SE0546, SE0546A and SE0546B.

METHOD OF SENSORY ASSESSMENT

The panelists evaluated 9 samples of Wheat Puffs, over a period of 3 weeks.

Mean Sensory Scores were calculated for each sample according to attributes determined by the Trained Panels in a round table discussion.

Attributes were scored on a line scale of 0 - 100mm. The anchor points for each attribute are listed in **Table 1**.

COMPARISON OF SAMPLES

099	Sample # 1327, Low protein soft wheat	}
462	Sample # 1328, High protein hard wheat	}16% Barrel moisture & 325 rpm Screw speed
833	Sample # 1331, Low protein hard wheat	}
011	Sample # 1326, Low protein soft wheat	}
599	Sample # 1329, High protein hard wheat	}18% Barrel moisture & 325 rpm Screw speed
218	Sample # 1332, Low protein hard wheat	}
076	Sample # 1325, Low protein soft wheat	}
298	Sample # 1330, High protein hard wheat	}20% Barrel moisture & 325 rpm Screw speed
441	Sample # 1333, Low protein hard wheat	}

These samples were evaluated with respect to each attribute and the results are summarised in **Tables 2, 3 and 4**.

COMMENTS

LOW PROTEIN SOFT WHEAT VS HIGH PROTEIN HARD WHEAT

<u>16% Barrel Moisture</u>

The Low Protein Soft Wheat (1327) was perceived as being significantly;

- more Mouthdrying

than the High Protein Hard Wheat (1328)

<u>18% Barrel Moisture</u>

The Low Protein Soft Wheat (1326) was perceived as being significantly;

- weaker in Overall, Puffed Wheat and Dusty aromas
- weaker Smoked aftertaste

than the High Protein Hard Wheat (1329)

<u>20% Barrel Moisture</u>

The Low Protein Soft Wheat (1325) was perceived as being significantly;

- smaller Air Bubbles
- slower in Rate of Disappearance

than the High Protein Hard Wheat (1330) sample.

Low Protein Soft Wheat vs Low Protein Hard Wheat

16% Barrel Moisture

The Low Protein Soft Wheat (1327) sample was perceived as being significantly;

- darker in Colour
- weaker in Puffed Wheat aroma
- weaker in Overall flavour
- slower in Rate of Disappearance and Sticking to teeth less

than the Low Protein Hard Wheat (1331) sample.

18% Barrel Moisture

The Low Protein Soft Wheat (1326) sample was perceived as being significantly;

- weaker Overall and Dusty aromas

than the Low Protein Hard Wheat (1332) sample.

20% Barrel Moisture

The Low Protein Soft Wheat (1325) sample was perceived as being significantly;

- less Toothpacking

than the Low Protein Hard Wheat (1333) sample.

HIGH PROTEIN HARD WHEAT VS LOW PROTEIN HARD WHEAT

16% Barrel Moisture

The High Protein Hard Wheat (1328) sample was perceived as being significantly;

- darker in Colour
- weaker in Puffed Wheat aroma
- weaker in Overall flavour
- slower in Rate of Disappearance
- less Mouthdrying and Sticking to Teeth less

than the Low Protein Hard Wheat (1331) sample.

18% Barrel Moisture

The High Protein Hard Wheat (1329) sample was perceived as being significantly;

- stronger in Overall and Puffed Wheat aromas
- stronger in Smoked aftertaste
- more Toothpacking

than the Low Protein Hard Wheat (1332) sample.

20% Barrel Moisture

The High Protein Hard Wheat (1330) sample was perceived as being significantly;

- larger Air Bubbles
- faster in Rate of Disappearance
- less Toothpacking

than the Low Protein Hard Wheat (1333) sample.

C MARTIN
SENSORY TECHNICIAN

S M ALEXANDER
SENSORY CO-ORDINATOR

TABLE 1

ATTRIBUTES AND ANCHOR POINTS

PROJECT WHEAT - CRC

	ATTRIBUTES	ANCHOR POINTS	
Appearance	Colour	White	Light Brown
	Air Bubbles	Uneven	Even
	Air Bubbles	Small	Large
Aroma	Overall	Weak	Strong
	Puffed Wheat	Weak	Strong
	Dusty	Weak	Strong
Flavour	Overall	Weak	Strong
	Puffed Wheat	Weak	Strong
	Smoked	Weak	Strong
	Aftertaste, Smoked	Weak	Strong
Texture	Sticks to Teeth	Not Much	Much
	Rate of Disappearance	Slow	Fast
	Mouthcoating	Not Much	Much
	Crisp	Not Very	Very
	Toothpacking	Not Very	Very
	Mouthdrying	Not Very	Very

TABLE 2

MEAN SENSORY VALUES FOR

16% Barrel Moisture

099 Sample # 1327 Low Protein Soft Wheat
462 Sample # 1328 High Protein Hard Wheat
833 Sample # 1331 Low Protein Hard Wheat

ATTRIBUTES	099	462	833	SIGNIFICANCE	p-VALUE
Appearance:					
Colour	51.6	49.7	43.4	*	0.046
Air Bubbles	49.1	54.1	52.6	NS	0.678
Air Bubbles	43.1	45.4	34.1	NS	0.199
Aroma:					
Overall	34.3	30.4	41.9	NS	0.192
Puffed Wheat	17.9	22.3	40.6	**	0.006
Dusty	25.9	14.0	19.1	NS	0.113
Flavour:					
Overall	41.9	41.0	50.4	**	0.009
Puffed Wheat	29.6	30.9	39.4	NS	0.125
Smoked	18.6	22.9	25.4	NS	0.399
Aftertaste, Smoked	21.7	21.4	31.7	NS	0.102
Texture:					
Sticks to Teeth	48.0	46.6	63.6	*	0.031
Rate of Disappearance	46.3	56.4	66.4	**	0.008
Mouthcoating	35.9	38.4	46.0	NS	0.151
Crisp	47.6	53.0	61.0	NS	0.115
Toothpacking	45.0	50.6	59.7	NS	0.093
Mouthdrying	53.0	38.3	58.0	*	0.015

Significance levels:

p -Value:	0.000 - 0.001	***	=	0.1% Significance Level
	0.001 - 0.010	**	=	1% Significance Level
	0.010 - 0.050	*	=	5% Significance Level
		NS	=	Not Significant

TABLE 3

MEAN SENSORY VALUES FOR

18% Barrel Moisture

011 Sample # 1326 Low Protein Soft Wheat
599 Sample # 1329 High Protein Hard Wheat
218 Sample # 1332 Low Protein Hard Wheat

ATTRIBUTES	011	218	599	SIGNIFICANCE	p-VALUE
Appearance:					
Colour	48.3	44.4	52.4	NS	0.100
Air Bubbles	46.5	45.8	51.8	NS	0.497
Air Bubbles	44.8	49.5	46.4	NS	0.646
Aroma:					
Overall	26.8	35.6	44.5	***	0.001
Puffed Wheat	21.1	26.8	38.3	***	0.000
Dusty	7.6	16.8	13.4	**	0.003
Flavour:					
Overall	41.3	45.8	43.6	NS	0.349
Puffed Wheat	28.1	35.9	33.5	NS	0.143
Smoked	17.4	22.4	26.1	NS	0.133
Aftertaste, Smoked	17.1	18.3	26.4	**	0.008
Texture:					
Sticks to Teeth	44.8	45.6	48.1	NS	0.582
Rate of Disappearance	55.1	64.3	57.0	NS	0.191
Mouthcoating	37.3	37.8	39.6	NS	0.810
Crisp	63.0	66.1	61.0	NS	0.446
Toothpacking	37.8	33.8	47.0	*	0.046
Mouthdrying	34.9	42.6	37.5	NS	0.084

Significance levels:

p -Value:			
0.000 - 0.001	***	=	0.1% Significance Level
0.001 - 0.010	**	=	1% Significance Level
0.010 - 0.050	*	=	5% Significance Level
	NS	=	Not Significant

TABLE 4

MEAN SENSORY VALUES FOR

20% Barrel Moisture

076 Sample # 1325 Low Protein Soft Wheat
298 Sample # 1330 High Protein Hard Wheat
441 Sample # 1333 Low Protein Hard Wheat

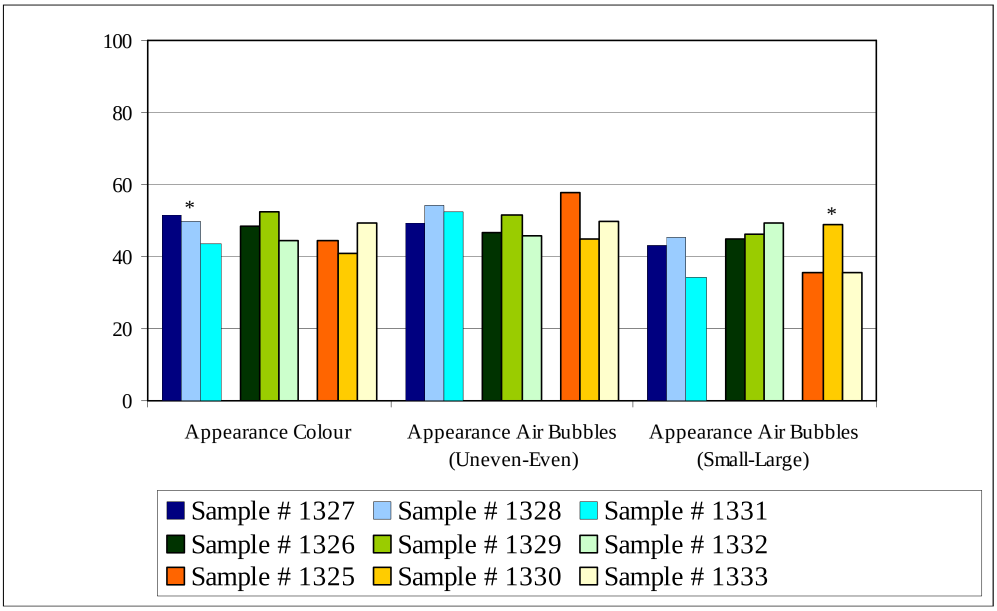
ATTRIBUTES	076	298	441	SIGNIFICANCE	p-VALUE
Appearance:					
Colour	44.6	40.8	49.1	NS	0.243
Air Bubbles	58.0	45.0	49.8	NS	0.129
Air Bubbles	35.5	48.8	35.4	*	0.032
Aroma:					
Overall	34.3	40.3	36.3	NS	0.502
Puffed Wheat	20.6	27.3	26.5	NS	0.174
Dusty	10.1	13.4	13.6	NS	0.375
Flavour:					
Overall	38.4	42.0	38.9	NS	0.688
Puffed Wheat	31.5	32.4	30.4	NS	0.798
Smoked	14.4	18.6	16.8	NS	0.486
Aftertaste, Smoked	12.8	15.0	17.3	NS	0.493
Texture:					
Sticks to Teeth	36.0	29.6	40.6	NS	0.341
Rate of Disappearance	54.6	67.4	53.0	*	0.015
Mouthcoating	39.9	32.5	41.5	NS	0.077
Crisp	66.4	67.6	62.4	NS	0.305
Toothpacking	31.5	28.0	43.9	*	0.011
Mouthdrying	41.9	35.3	40.0	NS	0.450

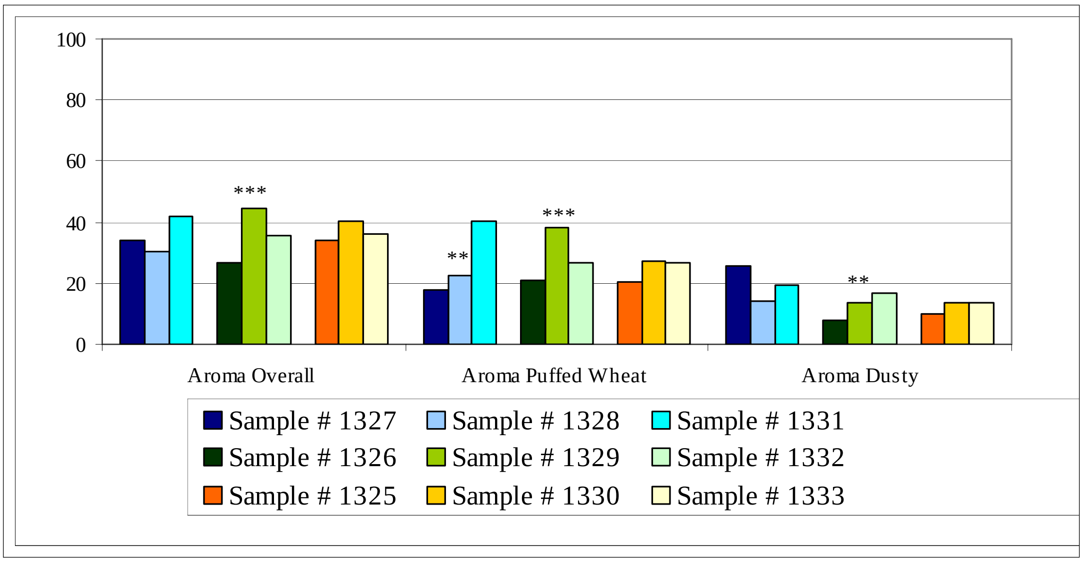
Significance levels:

p -Value:				
0.000 - 0.001	***	=	0.1% Significance Level
0.001 - 0.010	**	=	1% Significance Level
0.010 - 0.050	*	=	5% Significance Level
	NS	=	Not Significance

PROJECT WHEAT – CRC

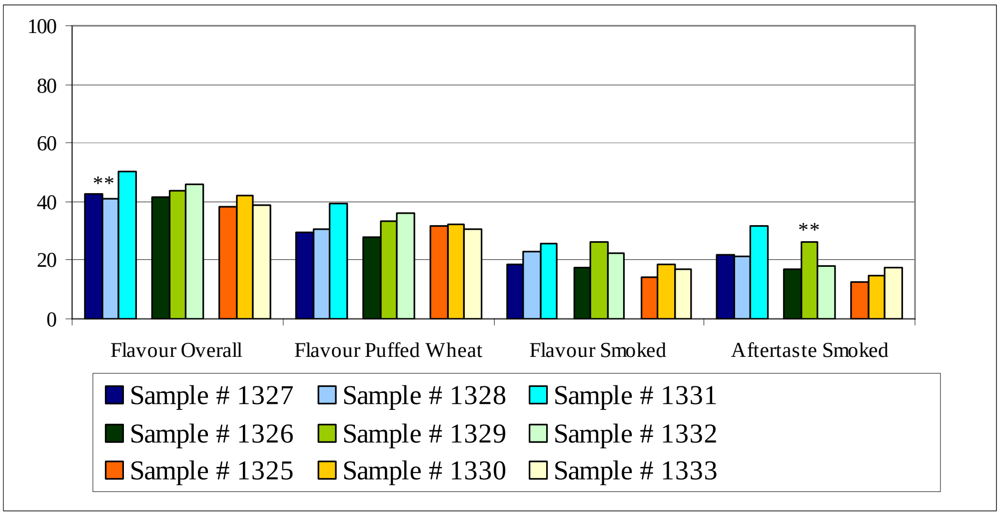
Summary of Sensory Evaluations SE0546, SE0546A & SE0546B

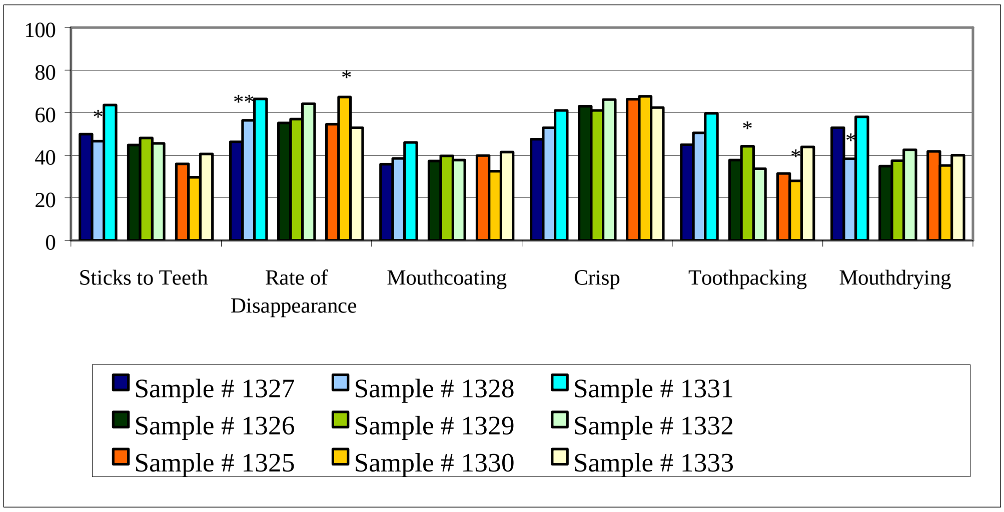




PROJECT WHEAT – CRC

Summary of Sensory Evaluations SE0546, SE0546A & SE0546B





APPENDIX 8

Optimisation of Extruder Conditions to Produce an Expanded Product of Acceptable Quality using Low Protein Hard Wheat

Protocol No: CW005

Protocol No: CW005 Optimisation of extruder conditions to produce an expanded product of acceptable quality using low protein hard wheat.

File Ref: c:\Wheat CRC\Protocol\CW005.doc

Background

In the previous trial (CW003), a twin screw extruder was used, operating under adiabatic conditions, and using processing settings as recommended by industry users to produce expanded products from three wheat flours. The sensory attributes of the products were tested for their appearance, aroma, flavour and texture. The outcome of the expert sensory panel evaluation on the three expanded products was that low protein hard wheat had significantly stronger aroma and flavour, more tooth packing, faster rate of disappearance, more mouth-drying and more sticking to teeth than low protein soft wheat. As these sensory evaluations indicate that a better snack product could be obtained from low protein soft wheat compared to low protein hard wheat, it is important to optimise the extruder conditions to produce a better product from low protein hard wheat.

For this experimental trial, low protein soft wheat will be used to produce an expanded product on a twin screw extruder operating under adiabatic conditions, and processing settings as recommended by industry users. Initially the same extruder conditions will be applied to low protein hard wheat and then adjusted to produce similar product characteristics as low protein soft wheat. The purpose of this trial is to eliminate the less favourable sensory attributes and validate the use of low protein hard wheat as a substitute for low protein soft wheat in expanded products.

Aim

To identify the operating conditions on Food Science Australia's twin screw extruder with low protein hard wheat to produce a product with similar sensory properties compared to using low protein soft wheat.

Experimental Plan

Extruder to be used,
Twin screw APV Baker MPF40,

Materials
Low protein hard wheat, Sr. No. 184 (8/9/98)
Low protein soft wheat, Sr. No. 183 (8/9/98)
Waratah Mill, Summer Hill

Methods

Experimental design
2 Wheat flours, 3 barrel moistures, two feed rates and one screw speed.

<u>Twin screw extrusion.</u>
Extrusion configuration
Medium barrel (15D), high shear screw configuration (No 29)
4D FS, 8x30° FP, 4D SLS, 2x90° FP, 7x30° RP, 1 SDS (Die end)

Extrusion Conditions
Die temperature: 180 °C at start up only, thereafter adiabatic
Barrel Temperature: 150 °C at start up only, thereafter adiabatic
Feed Rate: 25 and 30 kg/h
Die: one 4mm diam, land length, 12.6 mm (k = 0.5)
Die Pressure: 500-1,100 psi
Cutter: 2 blade

Processing Variables
The rationale is in order to get the same product from the two wheat types, it should have the same die melt and the same barrel zone 9 melt temperatures. Then, under the same temperatures, the ratio of melted and gelatinised starch in the 2 types of extruded wheat will be the same. An attempt will be made to match die melt and barrel zone 9 melt temperatures of low protein soft wheat, by altering the barrel moisture content of low protein hard wheat for a given feed rate and screw speed under adiabatic conditions.

Trial No.	Wheat type	Feed rate (kg/h)	Screw speed (rpm)	Moisture (%)	Die melt Temp(°C)	Zone 9 melt Temp(°C)	No. of samples
1	LPSW	30	325	16	Record	Record	1
	"	30	325	18	Record	Record	1
	"	30	325	20	Record	Record	1
2	LPSW	25	325	16	Record	Record	1
	"	25	325	18	Record	Record	1
	"	25	325	20	Record	Record	1
3	LPHW	30	325	16 ± x	Record	Matched temp to trial 1	1
	"	30	325	18 ± x	Record	Matched temp to trial 1	1
	"	30	325	20 ± x	Record	Matched temp to trial 1	1
4	LPHW	25	325	16 ± x	Record	Matched temp to trial 2	1
	"	25	325	18 ± x	Record	Matched temp to trial 2	1
	"	25	325	20 ± x	Record	Matched temp to trial 2	1

LPSW Low protein soft wheat
LPHW Low protein hard wheat

Collections
Duplicate 1 kg samples collected for each run condition and dried directly in dehydrator (50 °C overnight).

Measurements
Raw materials characterisation
Grain Hardness
Starch Damage
Starch Characteristics
Particle size
Water absorption/RVA
Gluten content and strength
Composition

<u>Processing Responses (logged with Citect)</u>
Die pressure
Melt temperature at barrel zone 9
Die melt temperature
Specific Mechanical Energy (SME)

<u>Extrudate Properties (measurements on duplicate sample collections)</u>
Radial expansion (Food Science Australia Method Manual for extrudates & raw materials)
Longitudinal expansion (“)
Specific volume (“)
Pasting curves (RVA) (“)
Texture (“)
Sensory attributes to be performed by Uncle Tobys Sensory Panel

Date started	**Date completed**
18-19/01/99	19/02/99

Results

Table 1: Extruder responses of low protein soft and hard wheat extrudates

Wheat variety	Sample No.	Feed Rate Kg/h	**Actual** Barrel Moisture calculated %	**Extruder Responses*** Melt 9 (°C)		Die melt (°C)		SME (KJ/Kg)		Die Press (psi)	
				Avg	SD	Avg	SD	Avg	SD	Avg	SD
Low	1401	30	15.6	188.7	0.6	147.7	0.4	646.2	5.5	1014	29
Protein	1400	30	17.8	178.6	0.7	146.7	1.7	638.5	9.1	940	64
Soft	1399	30	20	171.2	0.5	142.9	0.3	605.4	4.4	849	33
Wheat	1402	25	16.1	188.5	0.5	161.8	1.0	661.2	3.6	618	31
Sr. No.	1403	25	17.7	177.5	0.5	158.1	0.3	648.2	3.2	672	17
183	1404	25	19.8	168.4	0.5	152.7	0.9	636.1	3.6	643	13
Low	1407	30	16.4	188.0	0.0	165.1	1.7	628.2	5.2	862	17
Protein	1406	30	18.9	178.0	0.2	157.4	0.5	617.7	3.7	827	22
Hard	1405	30	20.2	171.8	0.3	150.7	0.4	604.7	4.6	869	29
Wheat	1408	25	15.1	189.4	0.4	180.1	1.0	653.1	5.5	547	9
Sr. No.	1409	25	18.5	177.3	0.4	172.8	0.5	606.0	2.4	620	10
184	1410	25	21.1	168.4	0.4	155.2	0.4	595.7	2.1	646	26

* Screw speed 325 rpm

Table 2: Product characteristics of low protein hard and soft wheat extrudates

Wheat variety	Sam. No.	Feed Rate (Kg/h)	Barrel Moisture (%)	PRODUCT CHARACTERISTICS: Product moisture* (%) Avg	SD	Specific vol. (ml/g) Avg	SD	REI Avg	SD	LE	Force max (N) Avg	SD	Hardness (N/mm) Avg	SD	Crsipness (+ peaks) Avg	SD	RVA Final viscosity (cP)
Low Protein Soft Wheat Sr. No. 183	1401	30	15.6	6.06	0.02	12.68	0.16	2.58	0.14	15.16	1.13	0.28	1.92	0.52	4.0	1.9	203
	1400	30	17.8	6.45	0.02	10.99	0.10	3.11	0.10	9.06	1.33	0.35	2.22	0.60	4.6	1.4	343
	1399	30	20	6.62	0.01	8.07	0.06	2.97	0.09	7.29	2.11	0.42	3.94	0.77	7.4	2.5	378
	1402	25	16.1	6.37	0.06	13.38	0.09	2.10	0.10	24.23	0.99	0.11	1.40	0.24	3.6	0.7	195
	1403	25	17.7	6.07	0.27	10.59	0.04	2.51	0.11	13.37	1.09	0.16	1.76	0.30	4.7	1.4	310
	1404	25	19.8	6.21	0.07	8.52	0.02	2.50	0.09	10.88	1.94	0.21	3.04	0.73	12.4	3.7	354
Low Protein Hard Wheat Sr. No. 184	1407	30	16.4	6.22	0.02	11.90	0.15	2.82	0.09	11.94	1.24	0.28	2.42	0.49	3.4	1.4	348
	1406	30	18.9	6.22	0.05	10.36	0.06	2.98	0.11	9.26	1.51	0.22	3.76	0.86	8.4	2.0	414
	1405	30	20.2	6.16	0.01	8.38	0.11	3.16	0.12	6.65	1.96	0.32	5.31	0.85	9.9	1.9	435
	1408	25	15.1	6.39	0.03	11.97	0.09	1.73	0.15	31.98	1.03	0.19	1.44	0.40	1.9	0.8	171
	1409	25	18.5	6.50	0.05	10	0.07	2.30	0.06	15.07	1.50	0.21	2.05	0.52	5.3	1.5	363
	1410	25	21.1	6.09	0.00	7.50	0.13	2.35	0.09	10.83	2.17	0.33	4.32	0.65	11.3	2.8	407

* After oven dried
REI Radial Expansion Index
LE Longitudinal Expansion

Discussion

Melt temperatures of the final barrel zone and at the die

The trial CW05 was carried out on a twin screw extruder to optimise the extruder conditions to produce an expanded product of acceptable quality using low protein hard wheat. Adiabatic conditions and processing settings recommended by industry were used throughout the trial with only the barrel moisture adjusted to produce similar product characteristics as low protein soft wheat. Initially, it was planned to match the melt temperatures of the final barrel zone and at the die with the corresponding melt temperatures of low protein soft wheat.

However, it was found out during the trial that an increment in barrel moisture of 5% was needed to match the die melt temperature of low protein soft wheat. At that barrel moisture level, the melt temperature of the final barrel zone was significantly lower (~20°C) than the corresponding melt temperature of low protein soft wheat. In addition, the product was less expanded and had significantly different appearance. Based on these extruder responses, an attempt was made to match only the melt temperatures of the final barrel zone of low protein hard wheat with corresponding melt temperatures of low protein soft wheat.

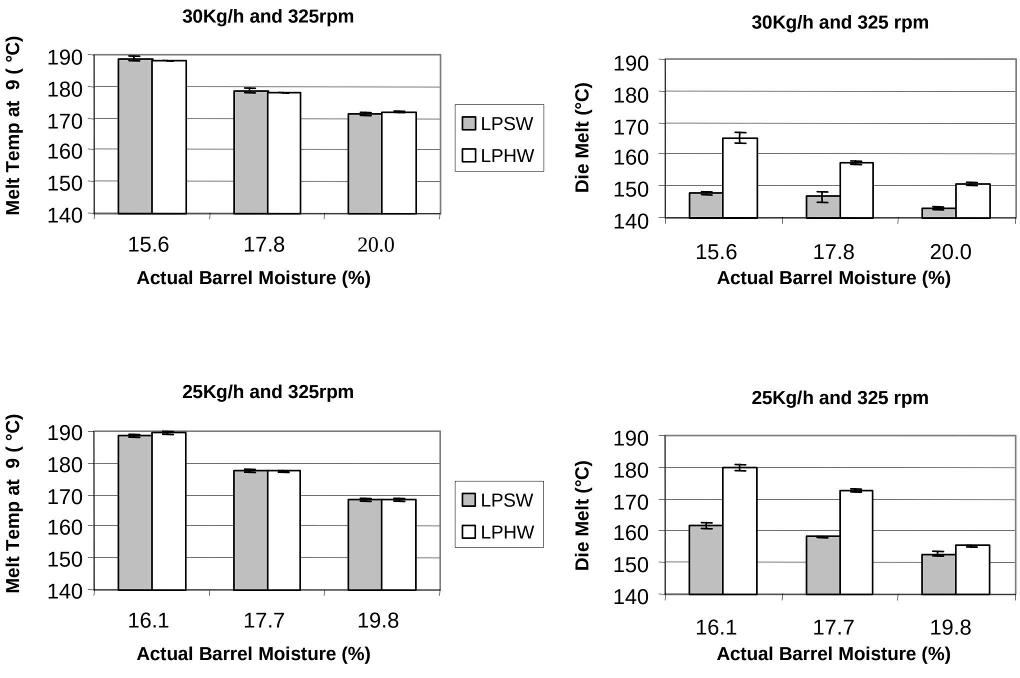


Figure 1: Melt temperatures of low protein soft and hard wheat at 30 and 25 kg/h feed rates

To match the melt temperature of the final barrel zone, low protein hard wheat required 0.2 – 1.3 % increment of barrel moisture than low protein soft wheat **(Table 1**). The die melt temperatures of low protein hard wheat were significantly higher than low protein soft wheat (**Figure 1**) at both feed rates and the difference in die melt temperatures were more pronounced at low barrel moisture runs.

At higher barrel moistures, the decrease in die melt temperature is attributed to water which acts as plasticizer to the starch material reducing its viscosity and SME. The higher die melt temperature for both wheats at the 25kg/h feed rate can be attributed to the less melted starch passing through the final barrel zone. Decreasing feed rate decreases the barrel fill and increases the residence time of the starch material.

Specific Mechanical Energy (SME) and Die Pressure

The specific mechanical energy of low protein soft wheat was higher for all moisture contents (**Figure 2**), and the low protein hard wheat always required the least amount of energy to produce expanded product in all trials (CW02, CW03 and CW05). The SME was found to be significantly dependent on moisture content and feed rate.

The effect of ageing is clearly seen in CW03 and CW05 trial results. SME began to increase as the flour aged (e.g. as the storage time lengthened, SME increased from 590 to 650 kJ/kg for low protein soft wheat and 590 to 630kJ/kg for low protein hard wheat at 16% barrel moisture). Studies done by others (Guy *et. al.*, 1987) showed similar results. They found that in high shear processing of white flour, SME increased from 460 to 540 kJ/kg, as the storage time lengthened.

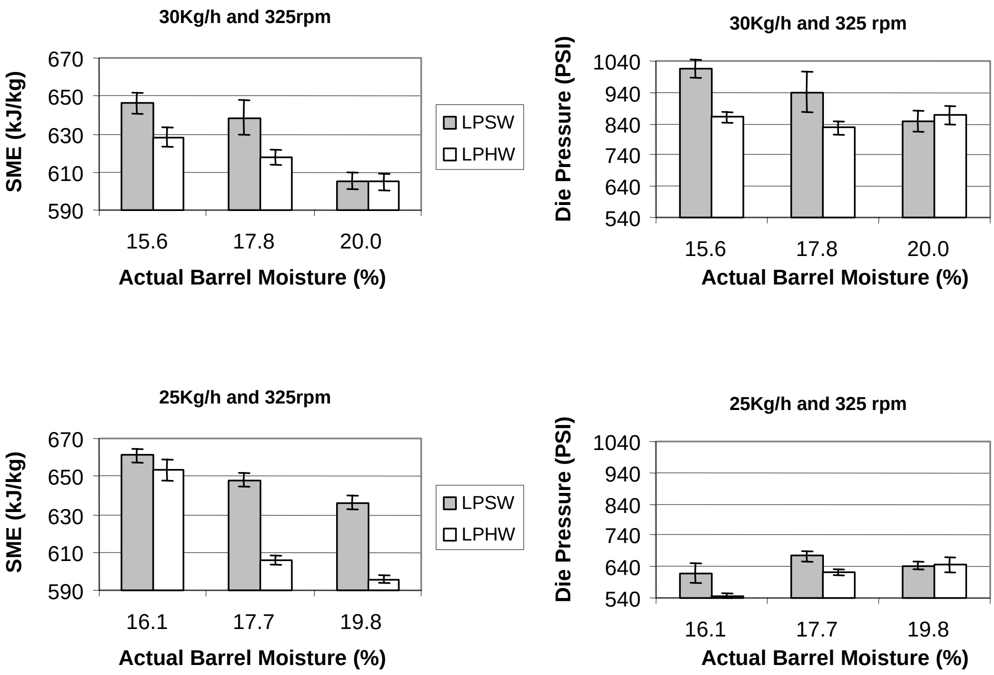


Figure 2: Specific mechanical energy and die pressure of low protein soft and hard wheat at 30 and 25 kg/h feed rates

The die pressures of low protein hard wheat were lower than soft wheat for all moisture contents except at 20% barrel moisture (**Figure 2**). The increased swelling of starch granules and reduced melting of starch indicates a low melt viscosity resulting in a low die pressure. The reason of higher die pressure at both feed rates for low protein hard wheat at 20% barrel moisture is not clear. A decrease in die pressure was observed at 25kg/h feed rate for both wheats. Decreasing feed rate decreases the degree of fill, and increases the residence time of the starch material.

Expansion

The overall expansion, measured as specific volume of low protein hard wheat, was slightly lower than low protein soft wheat, except for sample 1405 (**Fig 3**). The increment of 0.2-1.3% moisture in low protein hard wheat changes to 5-12% reduction in the specific volume. The changes were more prominent in 25kg/h feed rate. An increase feed moisture in the melt softens the molecular structure and reduces its elastic characteristics to decrease expansion. The ratio of radial to longitudinal expansion (table 3) results show that low protein hard wheat is more expanded radially at 30 kg/h feed rate compared to low protein soft wheat. However, the axial expansion of low protein hard wheat at 25 kg/h feed rate is greater than low protein soft wheat.

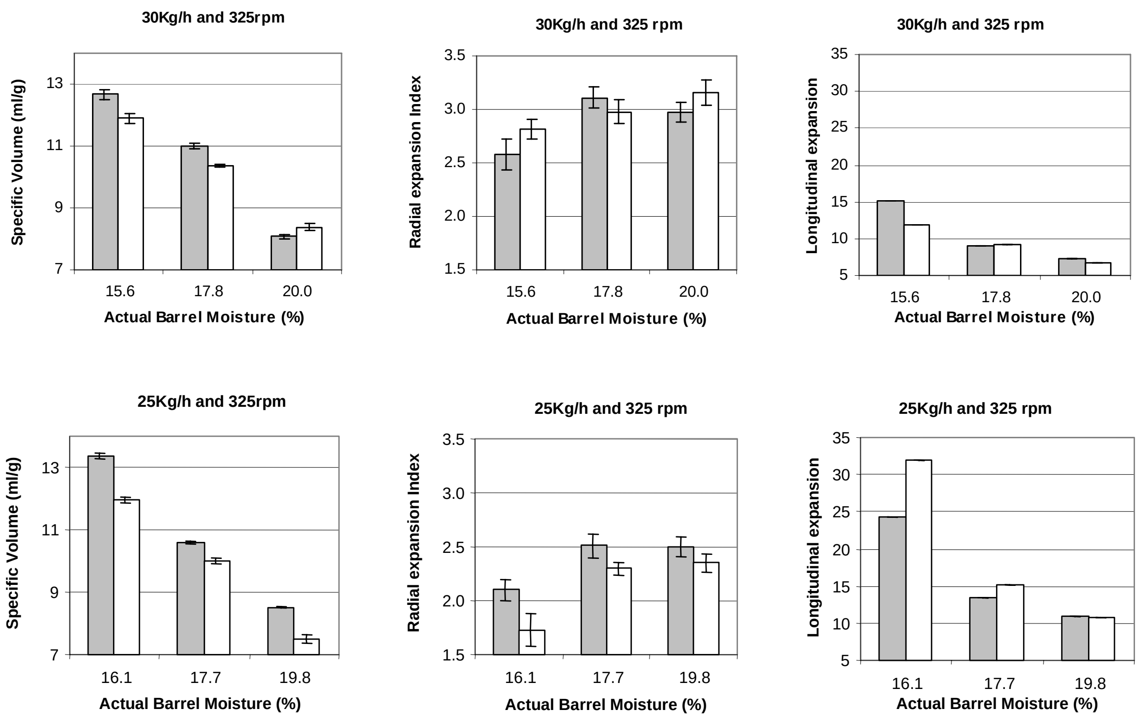


Figure 3: The expansion of low protein soft and hard wheat at 30 and 25 kg/h feed rates. Legends are the same as in Figure 1

These results suggested that under adiabatic conditions, an expanded product using low protein hard wheat will have the following operating conditions on a twin screw APV Baker MPF40 extruder:

Feed rate:	27-28kg/h
Barrel moisture:	18%
Screw speed:	350 rpm and
Screw profile:	high shear processing

Table 3: The ratio of radial to longitudinal expansion of low protein soft and hard wheat at 30 and 25 kg/h feed rates

Wheat type	Feed rate (kg/h)	Barrel Moisture (%)	RE/LE
LPSW	30	15.6	0.68
“	30	17.8	1.37
“	30	20.0	1.63
“	25	16.1	0.35
“	25	17.7	0.75
“	25	19.8	0.91
LPHW	30	16.4	0.94
“	30	18.9	1.29
“	30	20.2	1.90
“	25	15.1	0.22
“	25	18.5	0.61
“	25	21.1	0.86

RE/LE Ratio of radial to axial expansion

Texture

As would be expected, slightly harder texture was observed for low protein hard wheat due to its slightly increased barrel moisture. The hardness of low protein soft and hard wheat extrudates were marginally less at the lower feed rate.

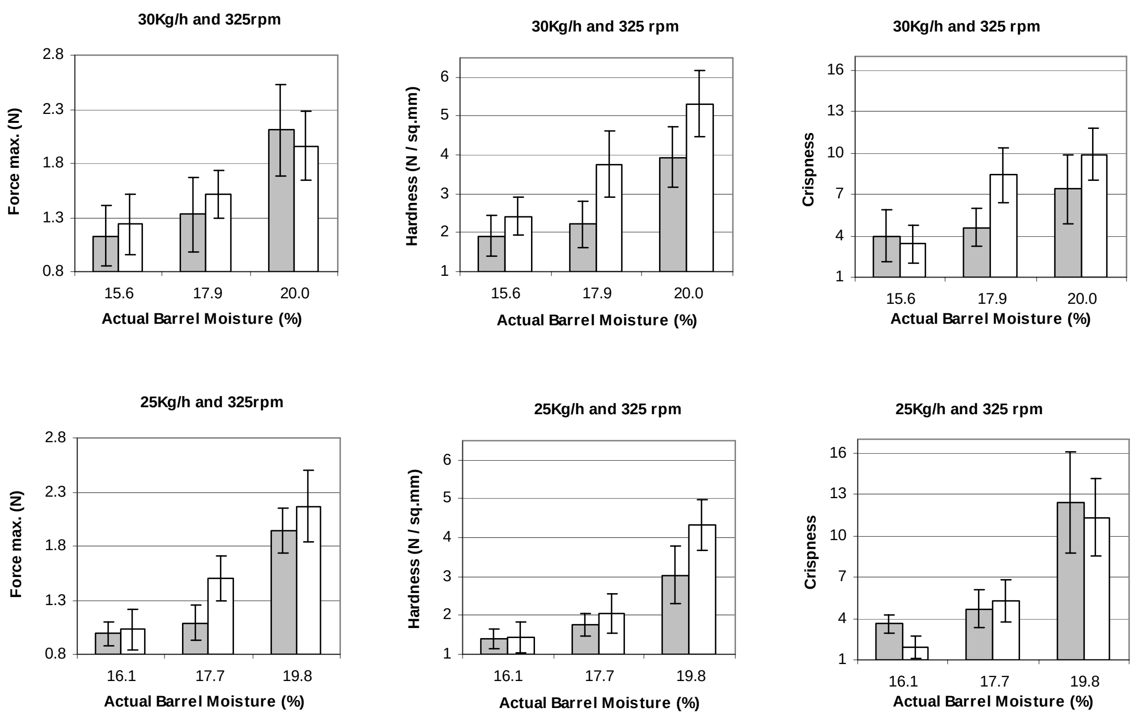


Figure 4: Texture of low protein soft and hard wheat at 30 and 25 kg/h feed rates. Legends are the same as in Figure 1

Rheology of low protein soft and hard wheat extrudates

The degree of processing or degree of cook (DOC) of an extrudate is normally observed from SME or motor torque. Rheology is the another approach to observe the starch structure changes due to processing. Rapid Visco Analyser (RVA) was used to determine all these changes on starch structure. The degree of cook is related to the cold paste viscosity which is resulted from the melted granule swell in water to increase viscosity. Cold paste viscosity increases and then decreases with degree of cook. However, viscosity also depends on molecular weight . Therefore highly dextrinised samples will exhibit a reduction in cold paste viscosity. Cold paste viscosities at 10% starch concentration of ground extrudates were measured with heating and cooling cycle loop (25°- 95°- 25°C) in 20 minutes in the RVA.

The low initial, breakdown and final viscosity indicate a high level of processing of starch material in an extruder. Initial, breakdown and final viscosity of low protein soft and hard wheats are shown in **Figure 5**. For both feed rates, low protein hard wheat was less cooked than soft wheat, except for sample 1408 (Barrel moisture 15.14% and feed rate 25 kg/h). The degree of processing on the two wheats related to the rheology of cold paste viscosity agrees well with SME trends. Low protein soft wheat appears to be more processed in the extruder at lower feed rates than low protein hard wheat.

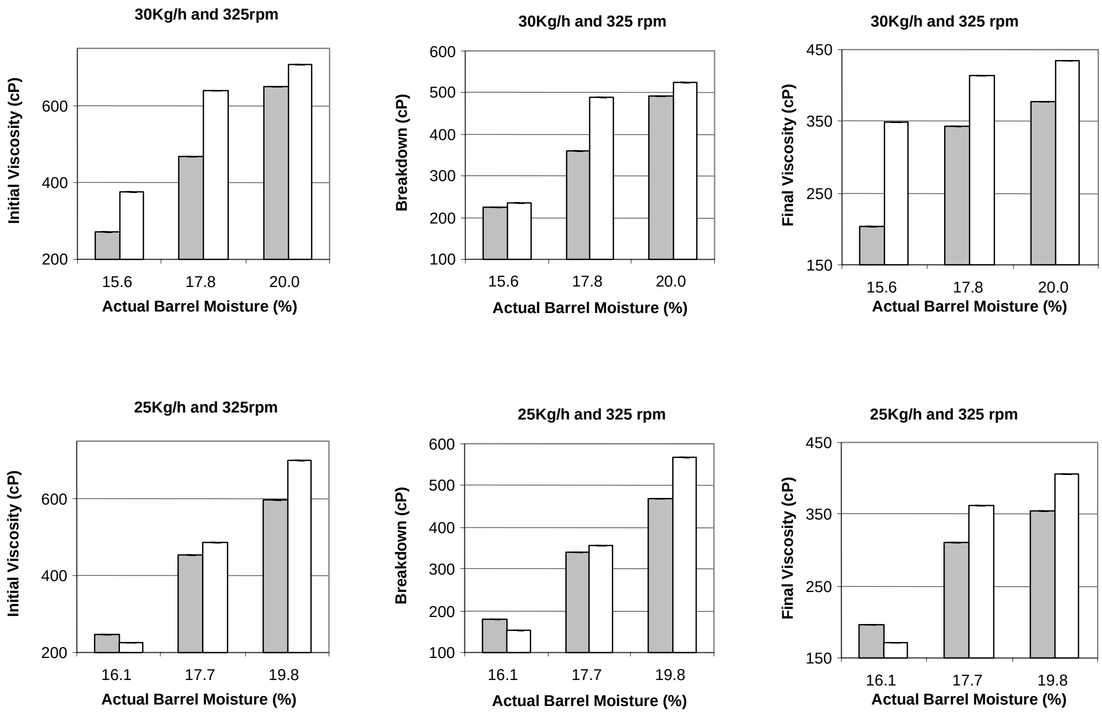


Figure 5: **RVA pasting properties of low protein soft and hard wheat at 30 and 25 kg/h feed rates. Legends are the same as Figure 1**

Conclusions

The results from this trial show that the physical product characteristics of low protein hard wheat is similar to low protein soft wheat. The subtle difference in physical product characteristics between two wheats is attributed to the slight difference in barrel moisture.

The main conclusions from this trial can be summarised as follows:

1. Low protein hard wheat produces a higher die melt temperature than soft wheat.

2. Low protein hard wheat requires less energy to produce an expanded product.

3. Slightly less expansion in low protein hard wheat extrudate can be related to increased barrel moisture content.

4. The overall texture of low protein hard wheat extrudate is slighter harder than soft wheat.

5. An increase in barrel moisture reduces the degree of processing in low protein hard wheat extrudate.

References

1. Guy RCE, Horne AW and Roberts SA. 1987 Extrusion cooking of wheat flour. Part II: Effects of ageing of flour and grain, and of the presence of bran. FMBRA Report No. 136.

2. Smart Extrusion Methods manual for extrudates and raw materials. Food Science Australia, Version 1,1999.

Future work

- To relate the results (physical attributes and processing conditions) with sensory properties of the extrudate.

- To carry out single screw extrusion trials.

EXPERT SENSORY PANEL EVALUATION

Table 1: Sensory attributes on CW05 samples

Product	After taste, 'Sweet'	'Dusty' Aroma	'Overall' Aroma	'Puffed Wheat' Aroma,	'Overall' Flavour	'Puffed wheat' Flavour	Air bubble, size	Air bubble, even-ness	First bite	'Rod'	Crisp-ness	'Ballsie'	Mouth Coating	Tooth Packing	Mouth Dryness	Stick-iness (to teeth)	Colour
LPSW, 20%BM 30kg/h FR	25.87	20.12	26.88	21.13	37.50	29.00	55.75	40.75	42.00	58.38	56.38	36.00	35.88	33.63	42.38	36.75	41.88
LPHW, 20%BM 30kg/h FR	18.12	19.25	35.38	26.37	41.75	33.63	49.62	43.50	50.50	50.75	51.75	47.00	29.63	36.75	38.63	28.38	35.63
LPSW, 20%BM 25kg/h FR	19.75	16.25	24.75	16.75	41.00	33.00	31.38	51.63	54.00	58.38	50.50	-0.00	29.88	38.38	40.13	43.50	38.87
LPHW, 20%BM 25kg/h FR	24.00	23.00	34.88	26.12	42.75	33.13	29.87	58.88	42.62	50.88	44.25	29.50	36.88	29.37	34.75	31.13	37.87
LPSW, 18%BM 30kg/h FR	9.75	12.12	35.25	27.63	41.37	32.87	48.38	48.75	49.43	57.75	57.25	33.25	42.13	46.50	46.75	44.88	47.13
LPHW, 18%BM 30kg/h FR	15.00	10.75	33.62	27.62	42.13	36.12	55.50	53.62	54.37	60.50	60.75	30.14	42.88	41.00	42.57	47.00	44.62
LPSW, 18%BM 25kg/h FR	6.87	13.87	30.00	22.37	42.63	34.75	39.87	57.11	46.87	55.75	61.88	35.62	34.00	46.25	44.25	53.50	57.75
LPHW, 18%BM 25kg/h FR	7.50	8.00	29.13	22.00	38.75	28.88	38.13	56.38	49.25	56.25	60.12	41.50	34.00	39.75	42.75	46.00	58.25
LPSW, 16%BM 30kg/h FR	12.75	20.37	35.13	24.63	40.38	32.50	45.75	51.63	47.62	61.88	60.37	34.50	48.62	48.25	45.00	56.25	49.00
LPHW, 16%BM 30kg/h FR	11.25	18.75	37.88	28.50	41.62	30.12	30.50	63.88	46.13	59.13	46.38	34.12	54.13	51.88	46.88	60.00	64.88
LPSW, 16%BM 25kg/h FR	12.25	19.75	35.87	26.75	42.37	34.63	35.88	57.38	41.50	66.25	51.63	35.75	46.63	63.87	55.00	65.62	64.25
LPHW, 16%BM 25kg/h FR	16.37	21.37	46.75	38.00	46.63	40.38	50.50	49.00	49.50	57.38	59.50	36.62	41.75	53.50	46.63	59.00	56.75

LPSW Low protein soft wheat
LPHW Low protein hard wheat
BM Barrel moisture (%)
FR Feed rate (kg/h)

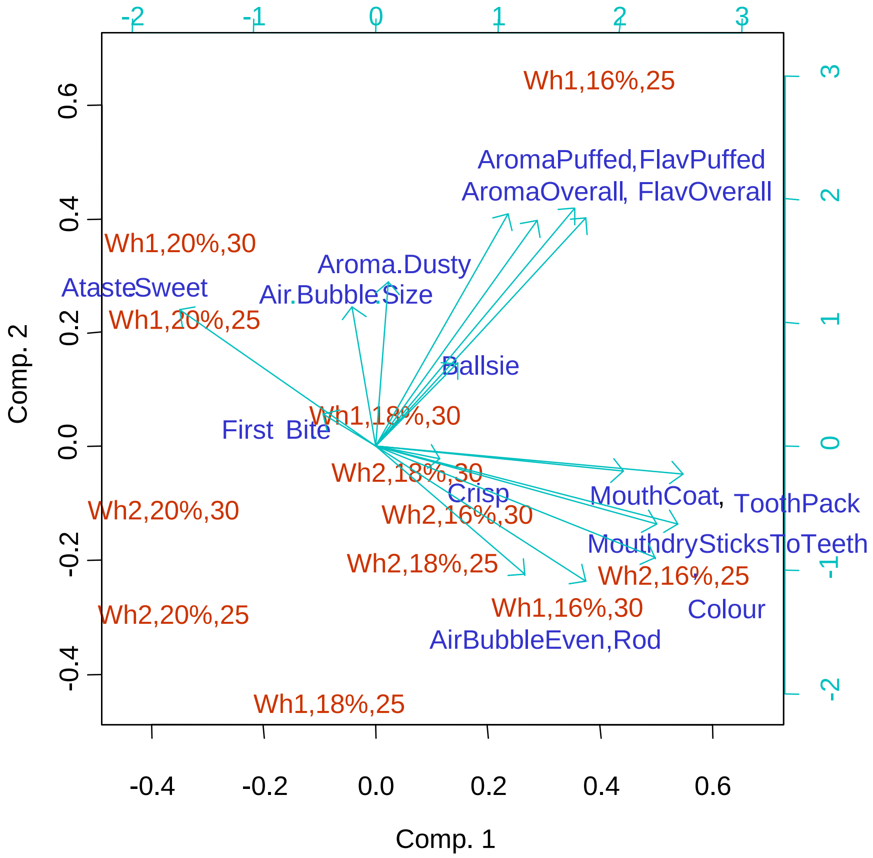


Figure 1: **Mapping of sensory attributes on low protein soft and hard wheat extruded at 3 barrel moistures and 2 feed rates.**

Legend: Wh1 = low protein hard wheat, Wh2 = low protein soft wheat, barrel moisture %, feed rate

In the previous trial CW05, it was demonstrated that low protein hard wheat could be used to produce a product with similar sensory properties compared to using low protein soft wheat. The 17 sensory attributes of the CW05 samples were measured and tabulated (**Table 4**). Two principle component analyses were performed. The first indicates the relationship between the individual products and the sensory attributes and the second, the relationship between the moisture settings and the sensory attributes (Maree O'Sullivan, CSIRO Mathematical and Information Sciences, PO BOX 52, North Ryde, NSW 1670). If the two products have similar sensory attributes they should be situated in the vicinity of each other.

The desirable sensory attributes in expanded products are air bubble size, first bite, crispness, air bubble evenness and colour. The less desirable ones are 'dusty aroma', strong 'puffed wheat' aroma or 'overall' aroma, strong 'puffed wheat' flavour or 'overall' flavour. Mouth coating or dryness, tooth packing or stickiness are also less desirable sensory attributes. It is likely that the less desirable flavour and aroma sensory attributes are resulted from the Maillard reaction products. The less desirable sensory attributes are probably the result of over-processing and the dextrinisation of starch. Perhaps the neutral sensory attributes of expanded products may have 'sweet' aftertaste, turns into a ball (ballsie) and rod (rod) in the mouth during chewing.

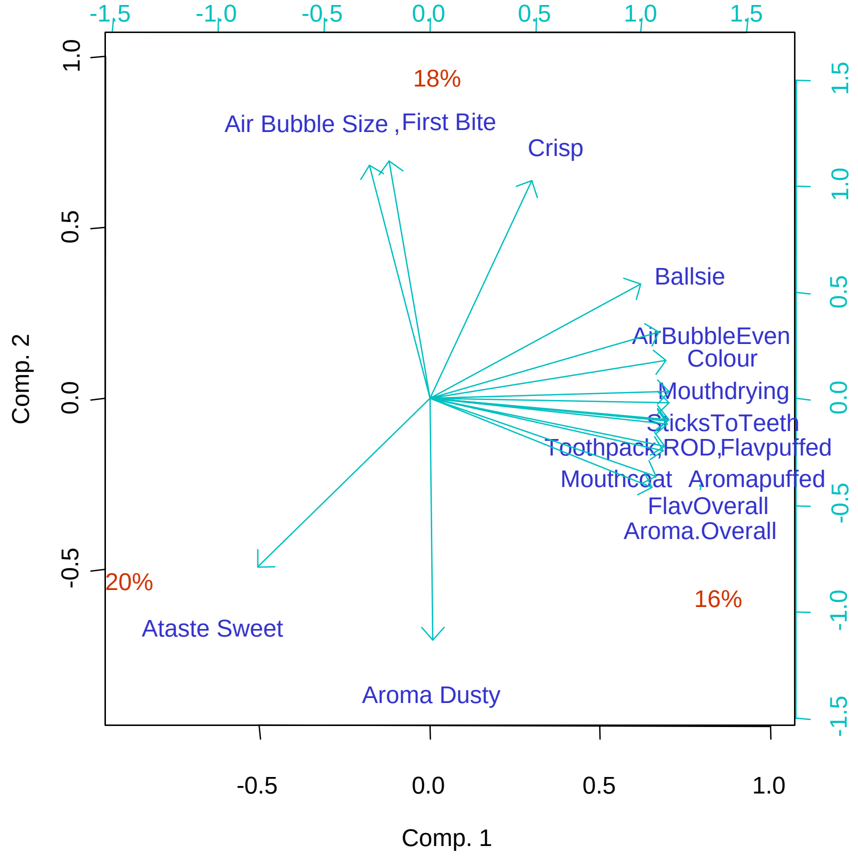


Figure 3: Mapping of sensory attributes on low protein soft and hard wheat extruded at the 16, 18 and 20% barrel moistures

From these results it appears that the 18% product is the crispest but perhaps the 16% have the most flavour (**Figure 3**). It can be seen from the figure 2 and 3 that the 18% barrel moisture product (Wh1,18%,30 and Wh2,18%,30) is the best product in terms of expansion and taste.

APPENDIX 9

Production of a Flavoured Snack using Low Protein Hard Wheat

Protocol No: CW007

Protocol No: CW007 Production of a flavoured snack using low protein hard wheat.

File Ref: c:\Wheat CRC\Protocol\CW007.doc

Background

From the trials carried out so far, it has been shown that an expanded products could be made with 100% low protein hard wheat on a twin screw pilot scale extruder. It has also been shown that the physical product characteristic of low protein hard wheat is similar to that of low protein soft wheat. The extruder operating conditions have been optimised to produce these products.

Based on these findings, It is proposed to produce a snack product (including flavours) using low protein hard wheat and compare its quality with low protein soft wheat. An attempt will be made to use the maximum amount of low protein hard wheat in the snack. It is proposed to develop formulations of wheat and maize flours (to increase expansion) together with appropriate minor ingredients.

Aim

To produce a low protein hard wheat /maize snack product in FSA twin screw extruder and to compare its properties with a control using low protein soft wheat /maize product.

Experimental Plan

Extruder to be used,
Twin screw APV Baker MPF40, FSA

Materials
Low protein hard wheat, Sr. No. 203 , 150 Kg, (31/03/99)
Low protein soft wheat, Sr. No.202 , 200 Kg, (31/03/99)
Maize flour, Polenta, Sr No. 204, 150 Kg, (31/03/99)
Vegetable oil (Palmoleine), Sr. No. ……
Flavouring – Cheese/Bacon, Sr No. ……
Salt

Methods
Experimental design
2 Wheat flours, around 18% barrel moisture to be adjusted as required, 25 kg/h feed rate and 325 rpm screw speed.

<u>Twin screw extrusion.</u>
Extrusion configuration
Medium barrel (15D), high shear screw configuration (No 29)
4D FS, 8x30° FP, 4D SLS, 2x90° FP, 7x30° RP, 1 SDS (Die end)

Extrusion Conditions
Die temperature: 150 °C at start up only, thereafter adiabatic
Barrel Temperature: 150 °C at start up only, thereafter adiabatic
Feed Rate: 25 kg/h
Die: one 4mm diam., land length, 12.6 mm (k = 0.5)
Die Pressure: 500-1,100 psi
Cutter: 2 blade

Formulations

Ingredients	**Formulation #1**	**Formulation #2**	**Formulation #3**	**Formulation #4**	**Formulation #5**
Low protein soft wheat flour	99.75*(100%)*	69.83*(70%)*	59.85*(60%)*	49.87*(50%)*	0
Low protein hard wheat flour	0	0	0	0	69.83*(70%)*
Maize flour	0	29.92*(30%)*	39.90*(40%)*	49.88*(50%)*	29.92*(30%)*
Vegetable oil					
Flavouring – Cheese/Bacon					
Salt	0.25	0.25	0.25	0.25	0.25
TOTAL	100	100	100	100	100

From the four formulations (1→4), an expanded product with the best acceptable quality will be selected. The ratio of LPHW and maize flour in the formulation 5 will be used from the selected formulation. These two products (LPSW & LPHW) will be used for flavour application.

Processing Variables

Collections
Duplicate 2 kg samples collected for each run condition and dried directly in dehydrator (50 °C overnight).
Quest international offers to apply flavour to the two formulations (LPSW and LPHW snacks).

Measurements
Raw materials characterisation
Grain Hardness
Starch Damage
Starch Characteristics
Particle size
Water absorption/RVA
Gluten content and strength
Composition

Processing Responses (logged with Citect)
Die pressure
Melt temperature at barrel zone 9
Die melt temperature
Specific Mechanical Energy (SME)

Extrudate Properties (measurements on duplicate sample collections)
Radial expansion (Food Science Australia Method Manual for extrudates & raw materials)
Longitudinal expansion (")
Specific volume (")
Pasting curves (RVA) (")
Texture (")
Sensory attributes to be performed by Food Science Australia, Werribee, Victoria Sensory Panel

Date started	**Date completed**
12/04/99	30/04/99

Results

1. Process results

Table 1: Extruder response and conditions of low protein soft wheat, low protein soft wheat/maize and low protein hard wheat/maize expanded products

Wheat variety	Sam. No.	Extruder response & conditions			
		Melt Temp at zone 9 (°C)	SME (kJ/kg)	Feed Rate (Kg/h)	Barrel Moisture (%)
LPSW (100% wheat)	1652	174	597	25	18
LPSW (70% wheat, 30% maize)	1653	170	602	25	18
LPSW (60% wheat, 40% maize)	1654	166	595	25	18
LPSW (50% wheat, 50% maize)	1655	165	594	25	18
LPHW (70% wheat, 30% maize)	1656	170	601	25	18.6

SME Specific Mechanical energy (kJ/kg)

To match the melt temperature of the final barrel zone, low protein hard wheat/maize (70:30) required 0.6% increment of barrel moisture than low protein soft wheat/maize (70:30) (**Table 1**). The low protein hard wheat/maize (70:30) required marginally less energy (Specific Mechanical Energy) than low protein soft wheat/maize (70:30) (**Table 1**).

2. Product characteristics (Non-sensory)

2.1. Expansion and texture

The overall expansion, measured as specific volume of low protein hard wheat/maize, was slightly higher than low protein soft wheat/maize expanded product (**Table 2**). This was attributed to the marginally higher radial and longitudinal expansion of low protein hard wheat/maize than low protein soft wheat/maize expanded product. The texture of low protein hard wheat/maize products was slightly harder and crispier due to the increment of higher barrel moisture (**Table 2).**

Table 2: Product characteristics of low protein soft wheat, low protein soft wheat/maize and low protein hard wheat/maize expanded products

Wheat variety	PRODUCT CHARACTERISTICS												
	Product moisture* (%)		Specific vol. (ml/g)		REI		LE	Force $_{max}$ (N)		Hardness (N/mm)		Crispness (+ peaks)	
	Avg	SD	Avg	SD	Avg	SD		Avg	SD	Avg	SD	Avg	SD
LPSW (100% wheat) Sample # 1652	5.72	0.01	10.59	0.01	2.73	0.20	11.27	1.32	0.18	2.65	0.99	9	2
LPSW (70% wheat, 30% maize) Sample # 1653	5.08	0.05	10.14	0.11	2.98	0.13	9.11	1.51	0.28	4.67	1.09	12	2
LPSW (60% wheat, 40% maize) Sample # 1654	5.41	0.02	10.02	0.14	3.02	0.09	8.75	1.92	0.39	4.71	1.63	16	2
LPSW (50% wheat, 50% maize) Sample # 1655	5.15	0.02	10.73	0.01	3.19	0.10	8.36	1.89	0.60	4.02	0.94	14	3
LPHW (70% wheat, 30% maize) Sample # 1656	5.08	0.04	11.04	0.02	3.07	0.16	9.30	1.59	0.25	3.05	1.17	15	2

* After oven dried
REI Radial Expansion Index
LE Longitudinal Expansion

2.2 RVA pasting property

Table 3: RVA pasting properties of low protein soft wheat, low protein soft wheat/maize and low protein hard wheat/maize expanded products

Graph Names	Peak 1	Trough 1	Breakdown	Final Visc	Setback	Peak Time	Initial Visc.	Peak Area
1652, LPSW 100%	387	154	366	425	271	5.1	523	427
1653, LPSW 70%, maize 30%	453	139	439	381	242	5.0	578	565
1654, LPSW 60%, maize 40%	486	122	525	379	257	5.1	648	681
1655, LPSW 50%, maize 50%	450	166	440	417	251	5.1	605	536
1656, LPHW 70%, maize 30%	409	123	419	348	225	5.0	542	541

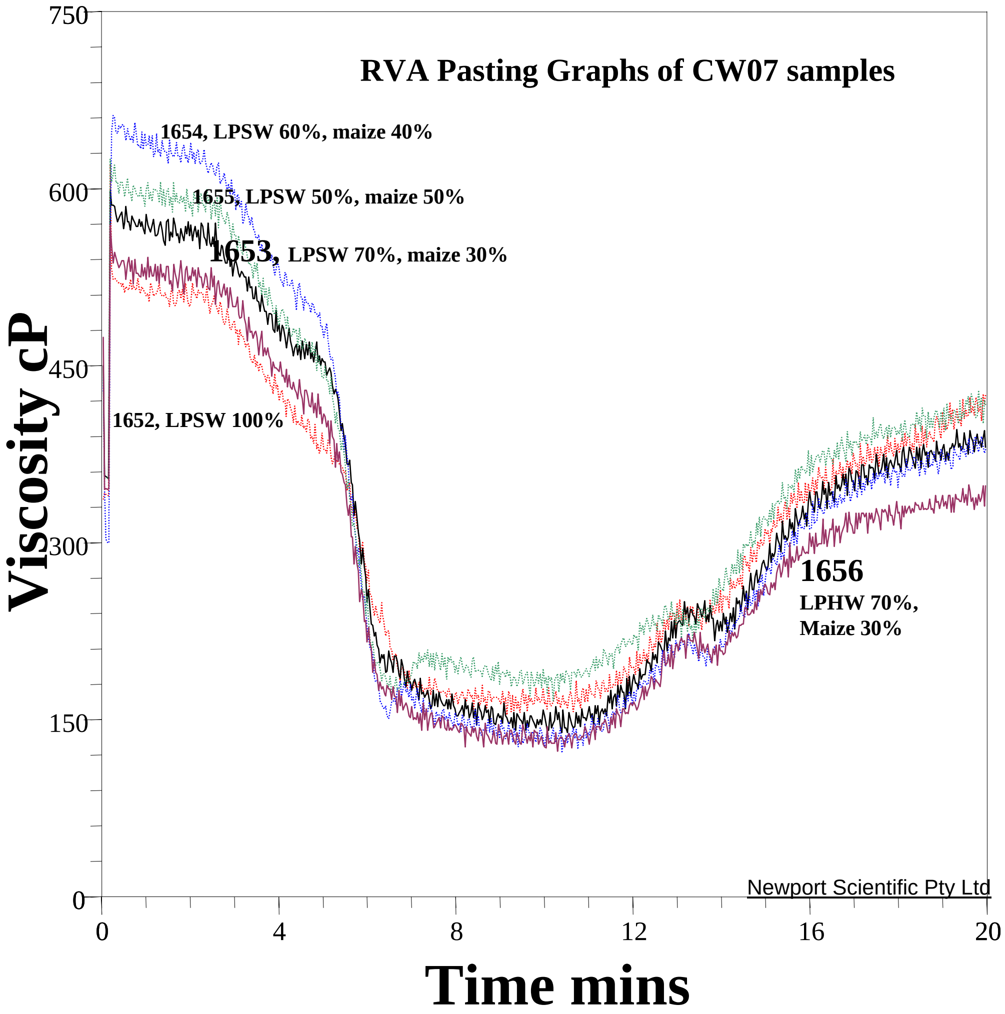


Figure 1: **RVA pasting curves of low protein soft wheat low protein soft wheat/maize and low protein hard wheat/maize expanded products**

The initial, breakdown and final viscosity of low protein hard wheat/maize was marginally lower than low protein soft wheat/maize product. This could indicate the same degree of processing on both products (SME 601 versus 602 kJ/kg).

The results from this trial show that the physical product characteristic of low protein hard wheat/maize (70:30) is similar to low protein soft wheat/maize (70:30). The subtle difference in physical product characteristics between two wheats is attributed to the slight difference in barrel moisture.

3. Sensory evaluation

From the statistical results performed on the sensory attributes of the previous trial (CW05 samples), Maree O'Sullivan, CSIRO Mathematical and Information Sciences, PO BOX 52, North Ryde, NSW 1670, it appears that the 18% product is the crispest but perhaps the 16% have the most flavour. The statistical results also indicate that the 18% barrel moisture product (LPHW, 18%BM, 30 kg/h FR and LPSW,18% BM ,30 kg/h FR) is the best product in terms of expansion and taste.

High feed rate increases the barrel fill and the die pressure. The final selection of the production of flavoured snack using low protein hard wheat was extruded at 18% barrel moisture and 25 kg/h feed rate. In the current trial (Protocol No. CW07) a lower feed rate (25 kg/h) was used because more expansion can be expected from the addition of maize flour.

A twin screw extruder operating under adiabatic conditions and processing settings recommended by industry have been be used throughout the trial (CW07) with only the barrel moisture adjusted to produce similar characteristics to low protein soft wheat. An attempt was made to match only the melt temperature of the final barrel zone of low protein hard wheat with corresponding melt temperature of low protein soft wheat.

The four expanded low protein soft wheat (sample 1652→1655) products were tested for consumer preference based on the following sensory criteria (**Table 4**).

Table 4: Sensory attributes tested on CW07 samples

Appearance	Colour	Light brown (1)	Yellow (10)
	Air bubbles, even	Unevenness (1)	Evenness (10)
	Air bubbles, size	Small (1)	Large (10)
Texture	Stickiness (to teeth)	Not much (1)	Much (10)
	Rate of disappearance	Slow (1)	Fast (10)
	Mouth coating	Not much (1)	Much (10)
	Crispness	Not very (1)	Very (10)
	Tooth packing	Not very (1)	Very (10)
	Mouth drying	Not very (1)	Very (10)

The preference testing of low protein soft wheat/maize samples were carried out by 20 untrained people (age between 24-60 yr., 13 Caucasian and 7 Asians, 14 male and 6 female). The preference scores were tabulated in **Table 5**.

Table 5: The preference scores on low protein soft wheat/maize expanded products

P R E F R E N C E SCORES (number of people, %)			
LPSW 100%, Maize 0% (Sam No. 1652)	LPSW 70%, Maize 30% (Sam No. 1653)	LPSW 60%, Maize 40% (Sam No. 1654)	LPSW 50%, Maize 50% (Sam No. 1655)
(5, 25%)	(7, 35%)	(7, 35%)	(1, 5%)

Based on the consumer preference score it was obvious that 70% or 60% wheat content in expanded product could not make any difference in product preference. As the objective of the trial is to maximum the use of low protein hard wheat in the product, the 70% low protein hard wheat 30% maize formulation was chosen to carry out these trials. Trials were also carried out with 70% low protein soft wheat 30% maize as a control.

These two products were coated with cheese/bacon flavour at Quest International flavour laboratory. The amount of 33g cheese/bacon flavour was mixed with 67g of Parmoleine oil and heated to 45°C. The heated flavour slurry was poured slowly onto the 100g snack which was preheated to 50°C. The product was rotated gently in a mixing bowl for 5 minutes. 100g batches were used to coat cheese/bacon flavour. The flavour-coated products were sealed in smell proof bags prior to sensory analysis.

3.1 Results from current trial (CW07 samples)

The sensory session was conducted on 28 April 1999 from 12.30 PM to 2.30 PM in the computerised sensory facility of Food Science Australia, Werribee.

Two cheese and bacon flavoured snack food products were tested. One was made with 70% low protein soft wheat and 30% maize (bag labelled 1653). The other product was made with 70% low protein hard wheat and 30% maize (bag labelled 1656).

The objective is to determine whether sensory panellists could detect a significant difference between two snack food products made from wheat of differing hardness.

A triangle test was used to determine whether a significant difference between the two products was detected by the sensory panel.

Each panellist was presented with three samples, two of one product and one of the other product. Panellists were asked to evaluate the three samples and to select the odd sample.

A balanced presentation order was used. Three pieces of the snack product were placed into each of the sample containers which were labelled with random three-digit codes.

Panellists who selected the correct odd sample in the triangle test were asked which sample they preferred and to comment on the difference(s) between the two types of samples.

A panel consisting of 50 Food Science Australia staff was used.

Evaluations were conducted under red lights.

Filtered water was used as a palate cleanser.

Triangle Test

A total of 22 panellists out of the 50 selected the correct odd sample in the triangle test.

The number of correct responses necessary to establish statistical significance at the different levels in the triangle test are presented in **Table 6** below.

Table 6: Number of Correct Answers Necessary to Establish Level of Significance for 50 Panellists

10%	5%	1%	0.1%
22	23	26	28

There is some suggestion that panellists were able to discriminate between the two products (p = 0.076). Although panellists did not detect a significant difference between the two products at the 5% level there was a significant difference at the 10% level.

The majority of the comments made by the panellists describing the difference(s) between the samples were on flavour (**Table 7**). There were only three comments on texture. Half of the 22 panellists perceived the product made with soft wheat as having a stronger bacon flavour than the product made with hard wheat. Four panellists perceived the hard wheat sample as having a stronger flavour than the soft wheat sample but the actual type of flavour was not specified in these comments. It is likely that they may have been referring to the cheese flavour since three other panellists specified the hard wheat product as having a more cheesy flavour. The cheese flavour may have been 'masked' by the stronger bacon flavour in the soft wheat product.

There are two possible explanations for these differences. The difference in flavour may be due to inconsistent application of the flavoured coating (batch to batch variation). Alternatively, a difference in texture between the two products may be affecting the flavour perception. That is, the softer texture may result in the perception of a more intense bacon flavour. It is possible that a combination of these explanations is also responsible.

Table 7: Summary of Comments Made by Panellists on Perceived Differences Between the Products

Soft Wheat Product		**Hard Wheat Product**	
Comment	**No. of Panellists**	**Comment**	**No. of Panellists**
Stronger (smoky) bacon flavour	11	Less of a bacon flavour and more cheesy flavour	3
Saltier	1	Stronger flavour	4
Less flavour	2	Texture totally different, interior seemed to dissolve in mouth	1
Softer texture, less flavour	1	Shape different – slightly elongated	1
Not gluggy, did not stick to palate	1		

<u>Preference</u>

Of the 22 panellists who selected the correct odd sample 13 panellists preferred the hard wheat product and 9 panellists preferred the soft wheat product.

These preference results should be treated with caution since some of the panellists may have guessed the correct odd sample.

There was no significant difference between the two products at the 5% level however there was at the 10% level.

In most cases, it appears that panellists discriminated between the samples based on flavour.

Conclusion

Based on these sensory evaluations it is concluded that the quality of the product made with low protein hard wheat is similar to the quality of the product made with low product soft wheat.

Future work

To complete final report (30 June 1999).