Effect of Flour Quality Characteristics on Puff Pastry Baking Performance

R. L. HAY[1]

ABSTRACT

The interrelationships of flour protein fractions quantified by reversed-phase high-performance liquid chromatography, monoclonal antibodies, near-infrared reflectance, dough properties, and puff pastry specific height and volume were investigated. Dough extensibility, measured with an Instron instrument, and both bread and pastry water absorption were closely related to the quantity of high molecular weight glutenin subunits. The role of low molecular weight glutenin subunits in mediating resistance to extension of a dough piece remains equivocal. Gliadin content did not correlate significantly with any dough properties or pastry quality parameters. Specific pastry height and volume were most strongly influenced by the rheological properties of the dough, particularly extensigraph tension energy. Bread baking performance was a poor indicator of the pastry baking quality of the same flour. Wheat cultivars displayed markedly different dough and pastry quality parameters, independent of country of origin.

Cereal Chem. 70(4):392-396

Over recent years, considerable effort has been expended on understanding and predicting the effect of wheat flour properties, especially the storage proteins, on bread quality. By comparison, the effort expended on understanding the effect on puff pastry has been small, with a largely technological or production, rather than fundamental, orientation. This is in spite of increases in pastry consumption throughout the developed world.

A basic puff pastry has a simple composition: flour, fat, water, and a little salt or food acid; but it has a complex physical structure. A flour-water dough is laminated with layers of fat and baked to produce the characteristic light flaky product. Despite this apparent simplicity, a consistently high-quality pastry is, in fact, difficult to manufacture. A wide range in finished product quality can be obtained depending upon the composition of the paste, quality of the flour and fat, and subsequent processing. A high-quality puff pastry is generally considered to be high in specific height and volume, with an acceptable texture or mouthfeel. In New Zealand, "acceptable" means that the pastry fragments are neither sharp to the palate nor gummy when chewed. In addition, there are a number of visual requirements, such as color (white or slightly yellow), and the absence of bran specks. In this study, only specific height and volume are considered.

Without reliable and readily accessible data on the importance of flour properties on dough performance, manufacturers tend to set fairly simple, and often arbitrary, flour specifications. In the U.S. and Europe, the flour protein and ash ranges are 12.0–14.5% and 0.4–0.5%, respectively. Typical flour specifications in New Zealand are 8.0–10.0% protein and <0.5% ash. Lower ash levels are specified if the pastry product is intended for export.

Rheological properties of flour-water dough are determined mainly by the protein composition and content of the flour. The functional properties of gluten protein are controlled by glutenins, which are large heterogeneous molecules (molecular weight up to several million) imparting tough and elastic dough characteristics, and by gliadins (molecular weight 30K–75K), which have a pronounced tackiness and ability to stretch (Wall 1979). A number of authors have demonstrated the importance of the quantity or ratio of these protein types in bread manufacture (Huebner and Beitz 1985, Dachkevitch and Autran 1989, Lundh and MacRitchie 1989, Marchylo et al 1989, Sutton et al 1989). The literature specifically related to the effect of these proteins on pastry quality is limited. Zabik and Tipton (1989) studied the effect on pie crust of reconstituting flour, in various combinations, that had previously had the protein extracted at four levels of acidity. They concluded that lift, strength, and surface blistering increased with increasing gliadin content, and that breaking strength increased at extremes of either gliadin or glutenin content. Increasing total protein content led to an increase in both lift and shrinkage and a decrease in surface blistering and breaking strength. Miller and Trimbo (1970), studying pie pastry and doughs of various formulation, obtained similar results between physical properties and total protein, with the exception that crust breaking strength increased with increasing total protein. Davies et al (1987) used a number of techniques to study the structure and functionality of protein in pastry doughs before and during baking. They found that high-quality pastry flours were able to form thin dough laminates (~30 μm), while inferior flours formed thicker, less well-defined layers. The conclusion was that, when thin, well-defined laminates were formed during pastry manufacture, lift during baking was governed by the mechanical properties of the heat-set laminates. Thus, the rheological properties before baking had the most significant influence on potential lift. Although Brabender extensigram energy (equivalent to tension energy) was recognized by most authors as an important parameter in determining pastry quality, only Geittner (1978) made a recommendation as to the preferred range (80–110 cm^2). The fundamental problem, well recognized by both millers and bakers (Tsourides 1968, Hawks 1988), is that any number of flours can be obtained that meet a given set of specifications, but the pastry-making performance of the flours is still different.

The aims of this study were to investigate the interrelationships of flour and dough characteristics and the effect they have on the specific height and volume of puff pastry. A better understanding of these interrelationships should allow identification of quality measurements of relevance for all sectors of the cereal food industry (from wheat breeders to pastry bakers) and allow better flour specifications to be set. Bread baking performance of the samples was also determined to ascertain whether this could be used as a measure of pastry-baking performance.

MATERIALS AND METHODS

Wheat

Twenty wheat samples were obtained from research laboratories and private companies within New Zealand and overseas. The selection criteria applied was that the samples from each source should reflect a wide range in expected pastry quality. It was not required that a sample be considered suitable for pastry manufacture. Eighteen of the samples were single cultivars and two were blends of an unknown number of cultivars. Nine cultivars (Advantage, Karamu, Kotare, Otane, Oroua, Rongotea, Takahe, Tiritea, and Weka) were obtained from the cool store of the Grain Foods Research Unit and were from the 1985, 1988, and 1990 New Zealand harvest bulks. Cultivars Becker, Caldwell, Compton, and Hillsdale were sourced from the United States; Fielder, Frederick, and SWS-52 from Canada; and Matong and Rosella from Australia. The two blends were obtained from a commercial

[1]Grain Foods Research Unit, New Zealand Institute for Crop and Food Research Ltd., Christchurch, New Zealand. The use of company, trade or product names in no way implies recommendation or approval by the New Zealand Institute for Crop and Food Research.

miller in New Zealand. These were Australian Standard White (ASW) and Dark Northern Spring (DNS), which are of Australian and U.S. origin respectively.

Flour Preparation

Wheat samples were tempered to 15.5% moisture before milling in a modified Buhler MLU 202 laboratory mill. The modification consisted of replacing the bolting cloth in the lower left and upper and lower right sieve trays (PA180/46, PA180/46, PA200/50xx, respectively) with PA150/51, PA150/51, and PA170/55 bolting cloths. Both the break and reduction flour were collected in three separate fractions. The final flour sample was prepared by blending the first and second break fractions with all three reduction fractions. The third break fraction was not included because of high Kent-Jones and Martin color-grade values and high levels of bran contamination. These modifications to the mill and flour-blending process lowered the overall flour yield of an Otane check sample from 70 to 57%, while giving a finer, whiter product that was comparable to commercial straight-run pastry flours found on the domestic (New Zealand) market.

Baking Tests

Pastry test-baking was carried out at the New Zealand Dairy Research Institute using a standardized in-house method. Doughs were prepared from 1,500 g of flour, 50 g of butter shortening, 9 g of potassium hydrogen tartrate, and sufficient water to make cohesive doughs of constant consistency after mixing. Each dough was then given the minimum mixing required for achieving clarity (2–2.5 min) using a hook beater (Bear Varimixer model 20/12, Wodschow & Co, Glostrup, Denmark). It was then rested for 15 min before incorporating 1,000 g of layering fat (a physically modified butter) by the French, or envelope, method (McGill 1975). The paste was then rested for 15 min more and gauged to 10-mm thickness in five steps (Rondo model STM503 Econom sheeter, Sewer AG, Burgdorf, Switzerland). Rough edges were trimmed from the paste sheet before further lamination via a two-fold turn, gauging to 8-mm thickness in three steps and a fourfold turn. After another 15-min rest period, the paste was trimmed again and given two fourfold turns (gauging to 7-mm thickness in six steps between each turn). A rest period of 15 min was allowed before final gauging to 2.5-mm thickness in 11 steps. Eight rings were cut from the paste using templates with an outer diameter of 90 mm and inner diameter of 50 mm. The thickness of each paste sheet and weight of each ring were recorded. The paste rings were then covered and rested for 1 hr before baking at 225°C for 11 min. After cooling, the pastry rings were evaluated for shrinkage, baked height, and volume by rapeseed displacement. Specific height and volume were calculated on the basis of raw pastry weights. For each sample, this procedure was repeated on a second, nonconsecutive day.

Assessment of the samples' bread baking quality was made by the Grain Foods Research Unit 125-g mechanical dough development (MDD) bake test as previously described by Mitchell (1984) and Swallow and Baruch (1986). Optimum levels of work input and water absorption were determined before duplicate bake testing. Loaf volume was determined by rapeseed displacement. A bake score comprised a volume component plus a subjective crumb grain component (scale 1–14) judged by trained personnel.

Sample Characterization

To characterize the flour samples, a number of analytical and physical tests were performed in duplicate.

Grain protein was determined by a standard micro-Kjeldahl method (N × 5.7) (AOAC 1981), and flour protein was determined by a Technicon InfraAlyser 400, suitably calibrated. Both high and low molecular weight glutenin subunits (HMW, LMW) and also gliadin (GLI) were quantified by reversed-phase high-performance liquid chromatography (RP-HPLC) using the methods of Sutton et al (1990) and Sutton and Hay (1990). Gliadins were extracted from flour (100 mg) at room temperature for 30 min, using 70% aqueous ethanol (2 ml). After centrifugation (48,000 × *g* for 20 min) they were analyzed by RP-HPLC. HMW glutenin subunits were prepared by preextracting flour (100 mg) at room temperature with 2% NaCl (w/v) (5 ml) to remove saline-soluble proteins and two volumes of 70% (v/v) aqueous ethanol (2 ml) to remove gliadins. The glutenin residue was reduced and extracted for 16–20 hr at room temperature with 0.1*M* Tris(hydroxymethyl)methylamine (2 ml, pH 6.8) containing 2% (w/v) sodium dodecyl sulfate and 1% (w/v) dithiothreitol. The reaction mixture was then centrifuged (48,000 × *g* for 20 min), and the clear solution used for RP-HPLC.

A Waters 600 solvent delivery-control system with a Waters WISP 712 automatic sample injector and a Waters 490 variable multiple-wavelength ultraviolet detector were used. The column was a 220 × 4.6-mm Applied Biosystems Aquapore RP-300 fitted with an 18 × 3.5-mm Applied Biosystems Aquapore RP-18 guard column. Eluted components were detected at 210 nm, and the chromatographic traces were recorded on a personal computer. Solvents used were: 1) water containing 0.06% (v/v) trifluoroacetic acid, and 2) acetonitrile containing 0.05% (v/v) trifluoroacetic acid. Deaeration was achieved by vacuum filtration through a 0.22-μm filter, rapid sparging with helium (100 ml/min for 10 min) and constant slow bubbling of helium into capped, vented solvent reservoirs (5 ml/min). Samples (20 μl) were injected onto the column, which was maintained at 70°C using a Waters column heater. A flow rate of 0.5 ml/min was used for both gliadin and glutenin analyses. Gliadins were eluted by a linear 48-min solvent gradient (24–48% acetonitrile) with a 12-min hold at the final solvent composition. Glutenin analysis was performed with a linear 42-min solvent gradient (27–48% acetonitrile), with an 18-min hold at the final solvent concentration. The column was returned to the initial solvent composition over 1 min and reequilibrated for 30 min before the next analysis.

The quantity of dough-strength-related HMW glutenin subunit was also estimated using the monoclonal antibody (MAb) based method reported by Skerritt (1991a,b) and Andrews et al (1991). This technique measures the absorbance of a chromophore released from the enzyme-linked immunosorbent assay at 405 nm.

Extensigraph testing was simulated using an Instron universal testing machine (model 1011), modified in a manner similar to that of Frazier et al (1985). Doughs were prepared from 125 g of flour and 2.5 g (2%) of NaCl mixed to optimum work input using the 125-g MDD mixer. Water addition was set 4% below the optimum 125-g MDD water absorption previously determined

TABLE I
Mill Yield, Damaged Starch, and Particle Size Distribution

	Milling Data					
	Mill[a] Yield	Damaged Starch	Particle Size Distribution[b]			
Sample	(%)	(%)	>70 μm	30–70 μm	10–30 μm	<10 μm
Advantage	57.5	9.1	74.5	15.6	9.9	0
ASW[c]	54.5	6.9	75.2	15.8	9.0	0
Becker	58.9	3.3	39.1	14.5	35.1	11.3
Caldwell	62.6	4.0	41.1	16.0	34.0	8.9
Compton	53.3	4.0	41.6	16.2	31.9	10.3
DNS[c]	56.5	6.1	73.6	16.8	9.6	0
Fielder	51.8	4.3	47.7	14.9	28.8	8.6
Frederick	57.2	4.3	48.7	14.1	30.0	7.2
Hillsdale	59.4	3.2	45.0	16.3	30.0	8.7
Karamu	49.8	6.0	66.9	17.9	11.6	3.6
Kotare	54.0	7.6	71.8	16.0	12.2	0
Matong	58.3	4.7	58.5	15.2	21.1	5.2
Oroua	56.9	7.4	75.6	15.0	9.4	0
Otane	54.2	7.6	74.0	14.6	8.1	3.3
Rongotea	56.7	7.0	71.6	15.6	12.8	0
Rosella	53.5	4.1	40.0	25.2	26.8	8.0
SWS-52	50.6	3.9	40.4	17.2	31.7	10.7
Takahe	61.5	7.2	70.4	16.9	9.1	3.6
Tiritea	60.4	7.4	68.8	17.3	9.9	4.0
Weka	55.9	6.8	68.4	17.1	10.5	4.0

[a] Mill yield (%) based on first and second break and first, second, and third reduction flour fractions.
[b] % (v/v) particles > 70 μm, 30–70 μm, 10-30 μm, <10 μm.
[c] ASW = Australian standard white; DNS = dark northern spring.

to produce doughs of readily workable consistency. Dough pieces were scaled off at 100.0 ± 0.1 g and moulded with a Mono universal table moulder set for 3.2-mm roll gap and 454-g pressure. After resting in a Brabender extensigraph dough cradle for 45 min at 30° C, (rh >85%), extensibility was measured by pulling the dough at 500 mm/min through a hook fixed to the Instron instrument. Tension versus time was recorded by a personal computer, and values of maximum resistance to extension, extensibility, and tension energy (directly equivalent to Brabender Extensigraph energy) were calculated from the data using a customized routine (ASYST 1990). Damaged starch was determined using AACC method 76-30A (AACC 1983). Flour particle diameter was estimated using a Malvern Instruments 2600C laser droplet and particle sizer. Results were expressed as percent (v/v) of the sample falling into each of up to four modes or peaks identified from the output. These ranges were: >70 μm, 30–70 μm, 10–30 μm, and <10 μm.

All statistical analyses of data and preparation of linear models were carried out using the SAS software package (SAS 1987).

RESULTS AND DISCUSSION

Milling yields, damaged starch values, and particle size distributions for all cultivars are shown in Table I. Flour protein quantity (total, gliadin, and glutenin), dough properties, and baking data (pastry and bread) are summarized in Table II, with

TABLE II
Protein Quantity, Flour Work Input and Water Absorption, Extensibility, and Bread and Pastry Baking Data

	Flour Protein[a]					Dough Property[b]						Baking Quality[c]		
Sample	GLI	HMW Glutenin	LMW Glutenin	MAb	Flour Protein	Work Input	Water Absorption	Pastry Water Absorption	EXT	Rmax	Tension Energy	Loaf Volume	Specific Pastry Height	Specific Pastry Volume
Advantage	82,756	14,654	48,460	0.18	8.8	19.1	56.5	48.5	19.9	8.3	133	720	1.85	4.76
ASW[d]	111,761	20,720	65,754	0.25	11.0	30.2	61.0	48.0	25.8	9.5	215	828	1.93	6.19
Becker	60,664	10,293	36,541	0.20	6.7	22.7	49.0	42.0	17.2	8.9	124	810	1.33	3.91
Caldwell	61,252	12,064	37,675	0.21	7.2	36.0	49.0	41.0	21.0	9.7	169	810	1.55	4.94
Cómpton	64,167	13,536	55,451	0.23	9.2	34.2	51.5	44.0	20.8	11.7	208	846	2.68	6.65
DNS[d]	122,867	22,870	84,588	0.80	13.4	49.0	63.0	48.0	29.8	11.1	258	900	2.42	7.36
Fielder	103,682	16,020	50,036	0.23	9.9	17.3	57.0	46.0	25.3	1.7	36	720	1.30	4.54
Frederick	89,045	14,693	49,314	0.25	8.6	18.4	56.0	44.0	20.1	3.6	55	792	1.52	4.64
Hillsdale	83,323	10,159	35,120	0.18	7.7	14.4	50.5	42.5	18.6	3.2	51	864	1.15	3.77
Karamu	65,900	12,665	56,654	0.24	9.0	14.0	51.0	41.0	23.2	7.6	129	666	1.25	3.43
Kotare	62,929	16,915	64,796	0.22	9.0	25.2	61.5	51.7	21.0	6.8	121	810	1.82	4.76
Matong	86,995	16,904	53,247	0.28	9.4	32.4	56.5	43.5	22.8	14.3	262	810	2.09	6.02
Oroua	50,592	13,660	59,347	0.15	9.0	30.6	54.5	49.5	19.3	12.5	204	738	2.39	6.20
Otane	67,613	20,925	61,572	0.59	10.3	29.5	62.0	51.0	28.0	5.5	130	846	2.12	6.12
Rongotea	87,400	16,613	55,541	0.21	8.8	19.1	58.0	46.0	19.2	3.8	64	774	1.57	4.37
Rosella	74,689	18,020	74,036	0.39	10.0	33.8	59.0	46.0	27.4	10.4	241	882	2.02	6.68
SWS-52	91,892	18,013	51,533	0.31	9.0	31.3	56.0	43.0	24.8	4.9	105	738	1.40	4.07
Takahe	101,611	16,071	56,594	0.24	10.1	21.6	60.0	47.0	23.0	8.6	168	720	2.00	6.00
Tiritea	94,388	14,269	46,047	0.21	9.0	20.2	57.5	46.5	21.1	10.9	204	720	1.86	5.06
Weka	63,872	11,840	52,969	0.15	8.7	25.2	54.5	46.5	19.0	10.0	163	738	1.66	4.66

[a] GLI = gliadin, HMW = high molecular weight glutenin subunits, LMW = low molecular weight glutenin subunits (all peak areas in mV·s by reversed-phase high-performance liquid chromatography), MAb = monoclonal antibody response (absorbance at 405 nm), flour protein (% by near infrared).
[b] Work input = 125 g mechanical dough development (MDD) work input (KJ/kg), water absorption = 125-g MDD water absorption (% flour weight), pastry water absorption = water absorption for pastry doughs, EXT = extension to failure (cm), Rmax = maximal resistance to extension (N), tension energy in N·cm.
[c] Loaf volume = 125 g MDD loaf volume (ml), specific pastry height and volume in mm/g and ml/g, respectively, calculated relative to raw pastry weight.
[d] ASW = Australian standard white, DNS = dark northern spring.

TABLE III
Correlation Coefficients (*r*) of Selected Flour, Dough, and Pastry Parameters[a,b] (*n* = 20)

	Flour Protein	HMW Glutenin	LMW Glutenin	MAb	Work Input	Water Absorption	Pastry Water Absorption	EXT	Rmax	Tension Energy	Loaf Volume	Pastry Height
HMW glutenin	0.862***											
LMW glutenin	0.872***	0.803***										
MAb	0.759***	0.756***	0.680***									
Work input	0.527*	0.544*	0.580**	0.642**								
Water absorption	0.793***	0.884***	0.757***	0.569**	0.290ns							
Pastry water absorption	0.513*	0.560*	0.574**	0.280ns	0.173ns	0.788***						
EXT	0.831***	0.850***	0.729***	0.812***	0.536*	0.654**	0.286ns					
Rmax	0.178ns	0.035ns	0.278ns	0.079ns	0.581**	−0.024ns	0.057ns	0.036ns				
Tension energy	0.457*	0.337ns	0.520*	0.341ns	0.726***	0.234ns	0.165ns	0.361ns	0.934***			
Loaf volume	0.276ns	0.350ns	0.335ns	0.548*	0.598**	0.195ns	0.094ns	0.323ns	0.143ns	0.308ns		
Specific pastry height	0.556*	0.458*	0.610**	0.398ns	0.674***	0.423ns	0.518*	0.321ns	0.679**	0.747***	0.361ns	
Specific pastry volume	0.706***	0.618**	0.702**	0.564**	0.764***	0.539*	0.472*	0.564**	0.600**	0.770***	0.526*	0.910***

[a] GLI = gliadin, HMW = high molecular weight glutenin subunits, LMW = low molecular weight glutenin subunits (all peak areas in mV·s by reversed-phase high-performance liquid chromatography), MAb = monoclonal antibody response (absorbance at 405 nm), flour protein (% by near infrared). Work input = 125 g mechanical dough development (MDD) work input (KJ/kg), water absorption = 125 g MDD water absorption (% flour weight), pastry water absorption = water absorption for pastry doughs, EXT = extension to failure (cm), Rmax = maximal resistance to extension (N), tension energy in N·cm. Loaf volume = 125-g MDD loaf volume (ml), specific pastry height and volume in mm/g and ml/g, respectively, calculated relative to raw pastry weight.
[b] $^{*}P < 0.05$, $^{**}P < 0.01$, $^{***}P < 0.001$, ^{ns} not significant.

correlations between these variables shown in Table III. Qualitative variation in height and internal structure for a selection of pastry samples is shown in Figure 1.

Previous studies have shown that the quantity of HMW glutenin subunits, alone or in combination with other protein groups, could be used to obtain adequate predictive models for bread loaf volume (Dachkevitch and Autran 1989, Sutton et al 1989, 1990). Loaf volumes determined by the 125-g MDD bake test did not correlate significantly with specific pastry height and explain only 28% of variation in specific pastry volume scores. This demonstrates that bread baking performance cannot be used as an indicator of the pastry-baking quality of a sample, and that the models developed previously to predict loaf volume from protein components of flours do not hold in this context. Significant correlations were observed between flour protein, HMW, and LMW and specific pastry height; and between flour protein, HMW, LMW, and MAb and specific pastry volume. However, more significant correlations were observed between specific pastry height and dough-quality parameters such as 125-g MDD work input, maximal resistance to extension, and tension energy, and between specific pastry volume and work input and tension energy. Models predicting specific pastry height and volume on the basis of rheological performance and other flour characteristics are presented in Table IV (equations 1 and 2). Reasonable predictive capability was achieved using simple two-variable models; additional variables did not significantly increase predictive power. Tension energy was an important variable in modeling both specific pastry height and volume (Table IV, equations 1 and 2). As might be expected, maximal resistance to extension was the variable most strongly correlated to tension energy. Not surprisingly, the best model for tension energy used extensibility and maximal resistance to extension (model not shown). The quantity of HMW glutenin subunit was strongly related to extensibility (Table IV, equation 3), and is, therefore, likely to be important in governing the ability of the paste to withstand sheeting and subsequent handling during manufacture without rupturing the fine laminates or tearing the dough sheet. The model for maximal resistance to extension (Table IV, equation 4) is, however, much more equivocal, accounting for slightly under 49% of the observed experimental variation. Dough maximal resistance to extension appears to be related primarily to dough strength, although this feature of flour quality alone does not yield an adequate predictive model.

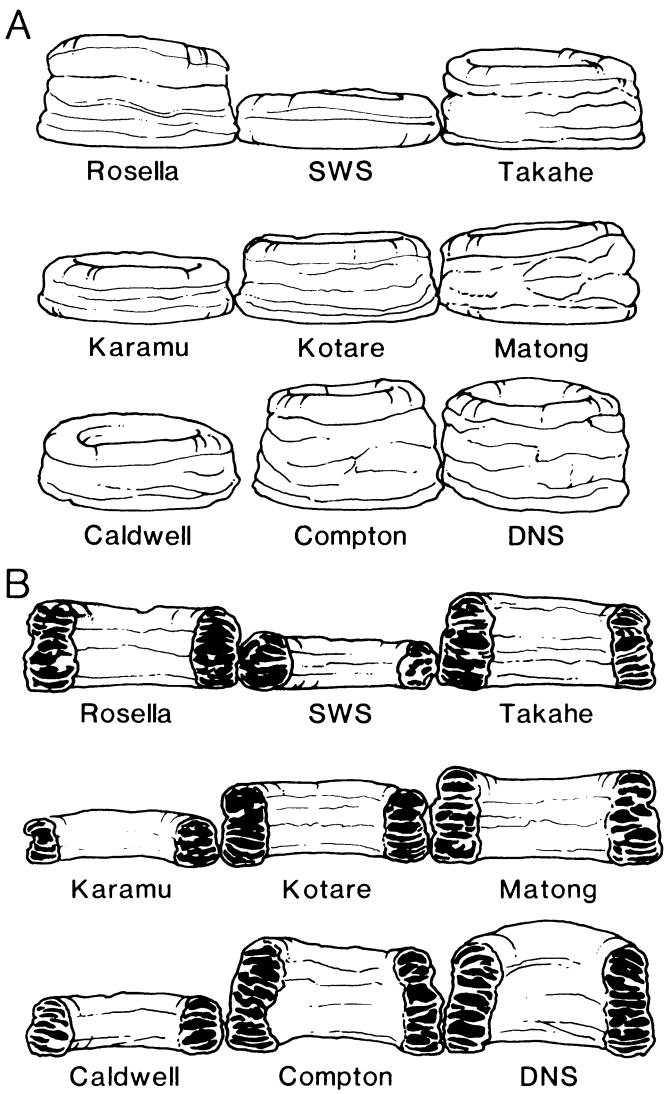

Fig. 1. Qualitative variation in height (**A**) and internal structure (**B**) of selected puff pastry samples. Country of origin is: Matong and Rosella, Australia; SWS, Canada; Caldwell, Compton, and DNS, United States; Karamu, Kotare, and Takahe, New Zealand.

No significant model was obtained for pastry water absorption (secondary variable in equation 1, Table IV). This is likely because of the subjective nature of assessment of this variable. Pastry water absorption is strongly correlated to bread baking water absorption, as determined previously, and it is presumably influenced by the same flour properties. A model accounting for 88% of variation was developed for water absorption (Table IV, equation 5) utilizing HMW glutenin subunits (partial $r^2 = 0.78$) and the percentage of flour particles within the 10–30 μm size band (partial $r^2 = 0.10$). Increasing damaged starch levels increases water absorption (Moss 1973). However, water absorption is a competitive process between damaged starch and gluten proteins. For this sample set, damaged starch alone accounted for only 31% of observed variation in water absorption. Statistical analysis revealed that all significant variation in water absorption attributable to damaged starch was also accounted for by HMW glutenin subunits. Hence, the inclusion of flour particle size in the model, which explains additional variation in water absorption not already accounted for by HMW glutenin subunits.

Both HMW and LMW glutenin subunit peak area correlated significantly with work input and water absorption, pastry water absorption, and also extensibility. LMW, but not HMW, correlated significantly with tension energy, the area under the extension-resistance curve. Neither correlated significantly with maximal resistance to extension. The monoclonal antibody test (MAb) is designed to predict dough strength by estimation of quality-related HMW glutenin subunit content of samples (Skerritt 1991a,b). Not surprisingly, therefore, correlations between dough properties (work input, extensibility, maximal resistance, and tension energy) and MAb score closely mirror those for HMW. MAb score correlated rather better with work input but less significantly with water absorption than HMW. However, MAb did not correlate with pastry water absorption, to which HMW correlated well. Both pastry water absorption and MAb are less precise measurements than their counterparts (water absorption and HMW respectively). This may have caused the loss of significance observed in the correlation.

The role of LMW glutenin subunits is poorly understood in both pastry and bread baking. The significant correlation between

TABLE IV
Models for Pastry Baking Quality and Dough Characterization

Equation	Model[a,b]	r^2	$P > F$
1	SPH = −1.3 + 0.0042 TE*** + 0.055 PWA**	0.718	0.0001
2	SPV = 0.6 + 0.0091 TE*** + 0.35 FP**	0.752	0.0001
3	EXT = 11.4 + 0.00055 HMW*** + 8.8 MAb**	0.789	0.0001
4	Rmax = 1.9 + 1.3 WI*** −11 MAb**	0.486	0.0035
5	WA = 44.3 + 0.0009 HMW*** −0.094 Fines**	0.884	0.0001

[a] $^{**}P < 0.01$, $^{***}P < 0.001$.

[b] Fines = % (v/v) of sample with particle size between 10 and 30 μm, SPH = specific pastry height, Rmax = maximal resistance to extension, TE = tension energy, FP = flour protein, HMW = high molecular weight glutenin subunits, MAb = monoclonal antibody response.

LMW and tension energy, and the relative strength of the nonsignificant correlations between LMW, HMW, and maximal resistance ($r = 0.278$ $P = 0.2349$ and $r = 0.035$ $P = 0.8842$, respectively) suggests that, in puff pastry manufacture, LMW glutenin subunits may act to increase resistance to extension. The results presented in Table II show that, for a flour to be suited to the manufacture of high lift and volume puff pastry, a combination of high extensibility and moderate-to-high resistance to extension is generally required. Also, increased glutenin content, as indicated by the pastry water absorption and flour protein (both highly correlated to HMW glutenin subunits) in equations 1 and 2 (Table IV), respectively, will further increase specific height and volume.

Zabik and Tipton (1989) considered it likely that gliadins contributed to pie crust shrinkage. In this study, gliadin peak area did not correlate significantly with any dough or baked good properties, including pastry shrinkage (data not shown). Due to the different methods of protein classification and performance testing used in these studies, this issue cannot be resolved at this stage.

Large differences in both baking quality and dough parameters were observed between cultivars. Because of the wide range in quality observed for cultivars from individual countries, country of origin cannot be used to discriminate between good and poor performing cultivars.

CONCLUSIONS

The results presented in this study of flours of diverse origin and quality show that dough properties, in particular tension energy and pastry water absorption, are the best predictors of specific pastry height and volume. These dough properties are largely, but not fully, explained by the qualitative and quantitative protein composition of the parent flour. The quantity of HMW glutenin subunits has been shown to be closely related to both extensibility and optimum (bread baking) water absorption. The role of LMW glutenin subunits has not been fully resolved. No statistically significant relationships could be found between flour gliadin content and any dough or baked pastry parameter. Bread baking performance of the flours (loaf volume) was a poor estimate of the pastry baking performance. Wheat cultivar strongly affects both dough properties and pastry quality.

Areas identified for further study include: the role of LMW glutenin subunits and their interaction with other protein components of flour; the effect of nonprotein variables, such as water addition, mixing energy/action, and resting time on dough rheology and baking quality; and the effect of both protein and nonprotein variables on baked pastry texture.

ACKNOWLEDGMENTS

This research was funded by the New Zealand Foundation for Research Science and Technology (FfRST). We gratefully acknowledge the assistance of the New Zealand Dairy Research Institute for performing pastry bake testing and flour particle size analysis; J. Skerritt and J. Andrews (CSIRO Grain Quality Research Laboratory, Australia) for supplying the monoclonal antibody assay; P. Williams (Grain Research Laboratory, Canada), J. Panozzo (Victorian Institute for Dryland Agriculture, Australia), and P. Finney (Soft Wheat Laboratory USDA, USA) for kindly supplying wheat samples; and D. Baird for statistical advice and assistance.

LITERATURE CITED

AMERICAN ASSOCIATION OF CEREAL CHEMISTS. 1983. Approved Methods of the AACC. Method 76-30A, approved May 1969, revised November 1972 and October 1984. The Association: St. Paul, MN.

ANDREWS, J. L., BLUNDELL, M. J., and SKERRITT, J. H. 1991. A simple, high-throughput test for dough strength. Pages 406-410 in: Cereals International, Proceedings of International Conference, Brisbane. D. J. Martin and C. W. Wrigley, eds. Cereal Chem. Div., Royal Australian Chemistry Institute: Victoria.

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS. 1981. Changes in Methods. Supplement to AOAC 13th ed., Vol. 64. Methods 24.B01 and 24.B03. The Association: Washington, DC.

ASYST 1990. ASYST 2.0. Software Technologies Inc.: Rochester, NY.

DACHKEVITCH, T., and AUTRAN, J. C. 1989. Prediction of baking quality of bread wheats in breeding programs by size-exclusion high-performance liquid chromatography. Cereal Chem. 66:448-456.

DAVIES, A. P., PATIENT, D. W., INGMAN, S. J., ABLETT, S., DRAGE, M., ASQUITH, M., and BARNES, D. J. 1987. Wheat protein properties and puff pastry structure. Pages 466-477 in: Proceedings of the Third Internationl Workshop on Gluten Proteins, Budapest. R. Lasztity and F. Bekes, eds. World Scientific Publishing Co.: Singapore.

FRAZIER, P. J., FITCHETT, C. S., and RUSSELL EGGITT, P. W. 1985. Laboratory measurement of dough development. Pages 151-175 in: Rheology of Wheat Products. H. Faridi, ed. Am. Assoc. Cereal Chem.: St. Paul, MN.

GEITTNER, J. 1978. L-Cysteine for the simplification of the manufacture of biscuits and puff pastry. Getreide Mehl Brot 32:124-126.

HAWKS, C. L. 1988. Flour protein quality. Pages 112-122 in: Proceedings of the 64th Annual Meeting. Soc. Bakery Eng.: Chicago.

HUEBNER, F. R., and BEITZ, J. A. 1985. Detection of quality differences among wheats by high-performance liquid chromatography. J. Chromatogr. 327:333-342.

LUNDH, G., and MacRITCHIE, F. 1989. Size exclusion HPLC characterisation of gluten protein fractions varying in breadmaking potential. J. Cereal Sci. 10:247-253.

McGILL, E. A. 1975. Puff pastry production. Baker's Dig. 49:28-38.

MARCHYLO, B. A., KRUGER, J. E., and HATCHER, D. W. 1989. Quantitative reversed-phase high-performance liquid chromatographic analysis of wheat storage proteins as a potential quality prediction tool. J Cereal Sci. 9:113-130.

MILLER, B. S., and TRIMBO, H. B. 1970. Factors affecting the quality of pie dough and pie crust. Baker's Dig. 44:46-55.

MITCHELL, T. A. 1984. Page G1 in: Proceedings of the International Symposium on Advances in Baking Science and Technology. C. Tseng, ed. Kansas State University: Manhattan.

MOSS, H. J. 1973. Quality standards for wheat varieties. J. Aust. Inst. Agric. Sci. 39:109-115.

SAS INSTITUTE INC. 1987. SAS/STAT Guide for Personal Computers, version 6 ed. SAS Institute: Cary, NC.

SKERRITT, J. H. 1991a. A simple antibody-based test for dough strength. I. Development of method and choice of antibodies. Cereal Chem. 68:467-474.

SKERRITT, J. H. 1991b. A simple antibody-based test for dough strength. II. Genotype and environmental effects. Cereal Chem. 68:475-481.

SUTTON, K. H., HAY, R. L., and GRIFFIN, W. B. 1989. Assessment of the potential bread baking quality of New Zealand wheats by RP-HPLC of glutenins. J. Cereal Sci. 10:113-121.

SUTTON, K. H., and HAY, R. L. 1990. Quantitation of rye in wheat/rye wholemeal mixtures by reversed-phase high-performance liquid chromatography. J. Cereal Sci. 12:25-32.

SUTTON, K. H., HAY, R. L., MOUAT, C. H., and GRIFFIN, W. B. 1990. The influence of environment, milling, and blending on assessment of the potential breadbaking quality of wheat by RP-HPLC of glutenin subunits. J. Cereal Sci. 12:145-153.

SWALLOW, W. H., and BARUCH, D. W. 1986. Loaf evaluation. Wheat Research Institute Report WRI 86/103. Depart. Sci. Ind. Res.: Christchurch, NZ.

TSOURIDES, K. N. 1968. Quality control for the pie baker. Baker's Dig. 42:32-38.

WALL, J. S. 1979. The role of wheat proteins in determining baking quality. Pages 275-311 in: Recent Advances in the Biochemistry of Cereals. D. L. Laidman and R. G. Wyn-Jones, eds. Academic Press: London.

ZABIK, M. E., and TIPTON, R. C. 1989. Pie crust quality: Influence of use of fractionated and reconstituted soft wheat flour of varied protein content. Cereal Chem. 66:313-317.

[Received September 25, 1992. Accepted January 28, 1993.]