Extrusion Properties and Cooking Quality of Spaghetti Containing Buckwheat Bran Flour

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ABSTRACT

The effect of hydration level on processing properties and the effects of hydration level, concentration of buckwheat bran flour and drying temperature on the physical and cooking quality of spaghetti were determined. Specific mechanical energy transferred to the dough during extrusion decreased 69% for semolina and 79% for semolina containing 30%, w/w, buckwheat bran flour, as hydration level increased 29–32% absorption. Little or no postdrier checking occurred in spaghetti made from semolina or spaghetti containing buckwheat bran flour when dried at high (70°C) or ultrahigh temperature (90°C). When dried at low temperature (40°C), tolerance to postdrier checking of spaghetti decreased as buckwheat bran flour increased 0–30% (w/w). Hydration level before extrusion did not affect cooking loss of spaghetti made from semolina. However, cooking loss was greater from spaghetti made with semolina-buckwheat bran flour that was hydrated to 32% compared with 29–31% absorption. Cooked firmness of spaghetti containing buckwheat bran flour decreased from 0.588–0.471 Nm as hydration increased from 29–32% absorption. Cooking loss was lower and cooked firmness was greater when spaghetti containing buckwheat bran flour was dried at ultrahigh than at low temperature.

Nontraditional ingredients such as buckwheat (*Fagopyrum esculentum* Moench) have been added to pasta to improve nutritional value and to provide potential health benefits to consumers (Marconi and Carcea 2001). Buckwheat protein contains high levels of essential amino acids and is rich in minerals, in vitamins B_1, B_2, and E, flavonoid rutin, and catechins (Oomah and Mazza 1996; Watanabe 1998; Steadman et al 2000, 2001b). In nutritional components, buckwheat bran flour is the milling fraction that is of most value. Buckwheat bran flour has a high concentration of protein 36%, lipid 11%, dietary fiber 15%, and minerals 7% (Steadman et al 2001a). Buckwheat bran flour also contains fagopyritols a galactosyl derivative of D-*chiro*-inositol that may be useful in the treatment of noninsulin dependent diabetes mellitus (Ostlund et al 1993).

Rayas-Duarte et al (1996) evaluated the quality of spaghetti containing buckwheat flour. They reported a change in texture and flavor in spaghetti containing 30% ground buckwheat endosperm and in spaghetti containing 15% whole ground buckwheat. Although research has been conducted to evaluate spaghetti containing buckwheat flour, none has been conducted using buckwheat bran flour.

The presence of nontraditional ingredients can affect processing characteristics through their effects on hydration and dough development. Nontraditional ingredients vary in their chemical composition and subsequent water binding properties. Nontraditional ingredients blended with semolina can affect hydration level needed for proper dough consistency for extrusion. For example, hydration levels needed for proper extrusion have been increased for semolina mixtures containing amaranth flour, buckwheat flour, or wheat bran and decreased for semolina mixtures containing lupin flour (Rayas-Duarte et al 1996; Manthey and Schorno 2002).

Nonwheat ingredients can result in discontinuity within the gluten matrix. The general deterioration in functional properties of dough containing bran is well documented in the literature (Bruinsma et al 1978; D'Appolonia and Youngs 1978; Zhang and Moore 1997; Manthey and Schorno 2002). Presence of bran particles physically interferes with dough development, which results in weak dough properties. Dough strength will affect the amount of mechanical energy required to extrude and the rate of extrusion (Levine 2001).

Reports have been published concerning the quality of pasta made with nontraditional ingredients (Rayas-Duarte et al 1996; Marconi and Carcea 2001; Lee et al 2002). These reports indicate that spaghetti containing nontraditional ingredients often had poorer cooking quality than spaghetti made only from semolina. Cooking quality of pasta containing nontraditional ingredients is generally improved by drying at high or ultrahigh temperatures (Malcolmson et al 1993; Marconi and Carcea 2001; Manthey and Schorno 2002). Drying at high temperatures denatures protein associated with the gluten matrix, which subsequently protects starch granules from rupturing during cooking. Furthermore, high temperature drying of pasta reduces water permeability and causes small changes in the packing and arrangement of starch granules, contributing to decreased cooking loss and increased cooked firmness (Vansteelandt and Delcour 1998; Yue et al 1999).

Limited information is available concerning the effect of nontraditional ingredients such as buckwheat bran flour on pasta processing and quality. The objectives of this research were to determine the effects of hydration level and buckwheat bran flour on extrusion and the effects of hydration level, buckwheat bran concentration, and drying temperature on cooking quality of spaghetti.

MATERIALS AND METHODS

Sample Preparation

Commercial semolina was obtained from the North Dakota State Mill (Grand Forks, ND). Minn-Dak Growers, Ltd (Grand Forks, ND) provided buckwheat bran flour. Buckwheat bran flour is a mixture of ground aleurone layer of seed, germ, and a very small portion of hull. Particle sizes of semolina and buckwheat bran flour were such that 87% of the semolina and 91% of the buck-

TABLE I
Proximate Analysis (%) of Semolina and Buckwheat Bran Flour[a]

Ingredient	Lipid	Protein	Ash	WG[b]	GI[c]
Semolina	1.0	13.1	0.70	34.2	19
Buckwheat bran flour	8.0	29.1	4.79		

[a] $n = 6$; 14% mb.
[b] Wet gluten.
[c] Gluten index.

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wheat bran passed through a 40-mesh (425 μm) screen. Semolina was fortified with buckwheat bran flour at 0, 10, 20, and 30%, w/w, and mixed 5 min using a cross-flow blender.

Sample Analysis

Approved Methods (AACC 2000) were used to determine ash (Method 08-01), protein (N × 5.7) (Method 46-30), wet gluten/gluten index (Method 38-12), and starch damage (Method 76-31). Dough strength was measured using the mixograph (National Manufacturing, Lincoln, NE) according to Approved Method 54-40A (AACC 2000). Optimum absorption for semolina (10 g, 14% mb) was calculated to be 63%. Absorption of 63% was used for all semolina-buckwheat bran flour blends. Lipid content was determined using a 16-hr Soxhlet extraction with hexane, Method Ba 3-38 (AOCS 1998).

Extrusion

Distilled water was added to semolina and semolina-buckwheat bran flour blends to achieve desired level of hydration. The wetted blends were mixed at high speed in a Hobart mixer for 4 min and placed in a mixing chamber and extruded as spaghetti using a DeMaCo semicommerical laboratory extruder under the following conditions: extrusion temperature 45°C; mixing chamber vacuum 46 cm of Hg; and auger extrusion speed 25 rpm. Hydration level, dough temperature, mechanical energy, and extrusion rate (g/sec and cm/sec) were recorded during extrusion of each sample. Specific mechanical energy (SME, kJ/kg) was calculated as the mechanical energy (kJ/sec) to extrude pasta divided by the amount of spaghetti extruded (kg/sec). The mechanical energy required to operate the empty pasta press was subtracted from the mechanical energy required to operate the press under load. To maintain similar extrusion rate and mechanical energy, hydration level was adjusted to 32% absorption for semolina; 31% absorption for 10% buckwheat bran flour; 30.5% absorption for 20% buckwheat bran flour; and 30% absorption for 30% buckwheat bran flour mixtures.

Extruded spaghetti was dried in a laboratory pasta dryer using low temperature (40°C), high temperature (70°C), and ultrahigh temperature (90°C) drying cycles (Yue et al 1999).

Spaghetti Quality

Brightness of dried spaghetti was measured with a colorimeter (model CR 310, Minolta Corp., Ramsey, NJ). Brightness readings were expressed by CIE values for *L*, where *L* values measure black to white (0–100). The number of white specks/m was determined by counting the white specks visible on 10 10-cm strands of spaghetti. Mechanical strength of dry spaghetti was measured by the work (Nm) required to break one strand of dried spaghetti. Mechanical strength was measured on four individual strands per sample using a TA-XT2 texture analyzer fitted with a spaghetti flexure rig (Stable Micro Systems Ltd., Surrey, UK). Diameter of dried spaghetti was determined by taking measurements at the midpoint of eight individual strands per sample. Susceptibility to postdrier checking was determined by placing 10 10-cm strands of spaghetti in a humidity chamber set at 80% rh and 23°C for 2 hr. The number of checks in the center 5-cm of each strand was determined.

Cooking Quality

Spaghetti (10 g) was cooked to optimum in 300 mL of boiling distilled water. Optimum cooking time for each sample was determined using Approved Method 66-50 (AACC 2000). Optimum cooking time corresponded to the disappearance of the white central core of the spaghetti. Cooking loss (wt of total solids %) was measured by evaporating the cooking water to dryness overnight in a forced-air oven at 110°C. Cooked firmness was measured with a TA-XT2 texture analyzer. Five cooked spaghetti strands were sheared at a right angle with a specially designed plexiglass tooth (Walsh and Giles 1971).

Experimental Design

Two experiments were conducted. The first experiment was designed to determine the effects of hydration level on processing and quality of spaghetti containing buckwheat bran flour. The experimental design of the first experiment was a randomized complete block with each treatment replicated three times. The second experiment was designed to determine the effects of buckwheat bran flour concentration and drying temperature on quality of spaghetti. The experimental design was randomized complete block with a split-plot arrangement of treatments. Whole plots were three drying cycles (low temperature, high temperature, and ultrahigh temperature) and subplots were four buckwheat bran concentrations (0, 10, 20, and 30%, w/w). Each treatment was replicated three times. All data were subjected to an analysis of variance using the Statistical Analysis System (SAS Institute, Cary, NC). Means were separated by Fisher's Protected LSD at the 5% level.

RESULTS AND DISCUSSION

Proximate Analysis

Proximate analyses of semolina and buckwheat bran flour are presented in Table I. Lipid, protein, ash, and wet gluten content of semolina are typical for durum wheat grown in North Dakota (Dick and Youngs 1988; Youngs 1988). Gluten index value of 19 indicates a moderately weak gluten. Strong gluten durum cultivars grown in the northern plains of the United States generally have gluten index values of 45–55 (F. A. Manthey, *unpublished data*). Mixograph dough development time increased 3.3–4.2 min while peak height decreased 5.9–5.3 cm as buckwheat bran flour concentration increased 0–20% (data not presented). Proper dough development did not occur with semolina containing 30% buckwheat bran flour.

Spaghetti containing 30% buckwheat bran flour could be made. In pasta processing, dough is developed inside the extrusion barrel where forward flow and back pressure act together to knead the dough. Pressure in the extrusion barrel can reach up to 12.7 MPa (Antognelli 1980). During kneading, a gluten matrix is formed by interaction among various gliadin and glutenin protein molecules. Starch granules become embedded in the gluten matrix as the dough develops.

Extrusion

Previous research found that optimum operating conditions for the pasta press used in this research were 32% semolina absorption, extrusion temperature 45°C, mixing chamber vacuum 46 cm of Hg, and auger extrusion speed 25 rpm (Debbouz and Doetkott 1996).

Extrusion of spaghetti at a constant screw speed (25 rpm) and dough temperature (45°C) was affected by hydration level of semolina and semolina containing buckwheat bran flour. SME transferred to the product decreased 69% for semolina and 79% for semolina containing buckwheat bran flour as moisture content increased 29–32% absorption (Table II). Increased hydration is associated with reduced dough viscosity (Abecassis et al 1994). At a given hydration level, buckwheat bran flour reduced SME transferred to product during extrusion. The low SME reflects the weak dough properties of semolina-buckwheat bran flour.

Energy required to extrude spaghetti declined 35% for semolina and 30% for semolina-buckwheat bran flour as moisture content increased 29–32% absorption (Table II). Interestingly, extrusion rates for semolina (measured as g/sec) were similar when hydrated to 29, 30, or 31% absorption. Hydrating semolina to 32% absorption reduced extrusion rate 16% compared with extrusion rate of semolina hydrated to 29–31% absorption. Extrusion rates for semolina containing 30% buckwheat bran flour was 58% slower when hydrated to 32% than when hydrated to 29% absorption. At a constant screw speed (25 rpm), the reduction in both the mechanical energy required to extrude and the rate of extrusion can be explained by a decrease in both dough viscosity and in friction between the dough and the interior barrel surface. It is possible that the lipid in the semolina-buckwheat bran flour mixture also could have reduced the friction between the dough and the interior barrel surface. A critical level of friction is required to promote proper movement of dough along the screw.

Although not measured directly, rate of feeding from the mixer into the extruder was noticeably slower for semolina-buckwheat bran flour hydrated to 31 or 32% absorption. Semolina-buckwheat bran flour hydrated to 31 or 32% absorption was noticeably sticky and during mixing it stuck to the walls and paddle of the mixer. Bridging over the opening between the mixer and extruder occurred with semolina-buckwheat bran flour hydrated to 32% absorption. Spaghetti strands did not stick to the drying rods or mat together during drying.

Extrusion rate (cm/sec) and energy required for extrusion were similar for semolina hydrated to 32% absorption and semolina-buckwheat bran flour hydrated to 30% absorption (Table II). Small differences in their extrusion rates based on g/sec were due in part to the different levels of hydration. To maintain similar extrusion rate and mechanical energy, hydration level was adjusted to 32% absorption for semolina, 31% absorption for 10% buckwheat bran flour, 30.5% absorption for 20% buckwheat bran flour, and 30% absorption for 30% buckwheat bran flour mixtures (data not presented).

Hydration level often has to be adjusted to obtain proper consistency of dough containing nontraditional ingredients. Hydration of ground whole wheat had to be increased from 32 to 33% absorption to achieve proper dough consistency for extruding spaghetti (Manthey and Schorno 2002). Rayas-Duarte et al (1996) increased hydration 2.6 percentage units before extruding a dark buckwheat flour-semolina mixture, 1.6 percentage units before extruding a light buckwheat flour-semolina mixture, and decreased hydration 1.7 percentage units before extruding a lupin flour-semolina mixture into spaghetti. Neither Rayas-Duarte et al (1996) nor Manthey and Schorno (2002) presented data on extrusion rate. The low level of hydration needed for semolina-buckwheat bran flour might relate to the lipid content of the buckwheat bran flour. The buckwheat bran flour used in this research and lupin used by Rayas-Duarte et al (1996) contained ≈8% lipid, while the lipid content of light buckwheat was 1.4 and dark buckwheat was 2.1%. Ingredients that contain higher levels of lipid would contain correspondingly lower levels of hydrophilic compounds and may require less moisture to reach similar level of hydration of the hydrophilic compounds.

Physical Quality

Spaghetti made with buckwheat bran flour had an uneven surface and varied in color from light brown (10% buckwheat bran flour) to dark chocolate brown (30% buckwheat bran flour). Brightness (*L*) generally decreased with increased level of hydration (Table II). Low hydration levels resulted in incomplete hydration of semolina. As hydration level increased 29–32% absorption, the number of white specks decreased from 34 to 8/m in spaghetti made from semolina and from 43 to 1/m in spaghetti containing 30% buckwheat bran flour (Table II). The white specks contributed to the brightness of spaghetti extruded at low hydration.

The drying temperature by buckwheat bran flour concentration interaction was significant for brightness. Brightness of spaghetti generally decreased with increased buckwheat bran flour and was less when dried using an ultrahigh temperature than a low temperature drying cycle (Table III).

The diameter of spaghetti strands (≈1.63 mm) was not affected by hydration level or by buckwheat bran flour concentration (data not presented). Hydration level did not affect mechanical strength of spaghetti made with or without buckwheat bran flour (data not presented), nor did it affect tolerance to postdrier checking of spaghetti made from semolina. Buckwheat bran flour reduced the mechanical strength and the tolerance to postdrier checking of spaghetti (Tables II and III). After 2 hr at 80% rh, spaghetti containing buckwheat bran flour had 9× more checks when extruded at 32% than at 29% moisture.

The drying temperature by buckwheat bran flour concentration interaction was significant for mechanical strength and for tolerance to postdrier checking. Mechanical strength and tolerance to

TABLE II
Effect of Hydration Level on Pasta Extrusion and Color, Diameter, and Checking of Spaghetti Dried at High Temperature

Ingredient	Hydration Level (%)	SME[a] (kJ/kg)	ME[b] (kJ)	Extrusion Rate (g/sec)	Extrusion Rate (cm/sec)	Density (g/cm^3)	*L*[c]	White Specks/m	Checks/m
Semolina	29	78.6d[d]	0.338f	4.3ef	1.6d	32.1c	63.5e	34d	2a
	30	48.6c	0.214e	4.4f	1.7e	30.7bc	62.0d	14b	0a
	31	39.7c	0.167d	4.2e	1.7e	30.2b	61.0c	11b	8a
	32	24.7b	0.089c	3.6d	1.4c	30.1b	60.5c	8b	0a
Semolina+BBF[e]	29	42.5c	0.183de	4.3ef	1.8f	28.6ab	31.6b	43e	10a
	30	25.3b	0.086bc	3.4c	1.4c	29.5ab	31.1ab	21c	34b
	31	18.5b	0.044ab	2.4b	1.0b	28.4a	30.9a	8b	50c
	32	9.1a	0.016a	1.8a	0.8a	28.4a	30.5a	1a	90d

[a] SME = specific mechanical energy.
[b] ME = mechanical energy.
[c] *L* values measure black to white (0–100).
[d] Values followed by the same letter in the same column are not significantly different ($P < 0.05$).
[e] BBF = buckwheat bran flour, 30% w/w.

TABLE III
Effect of Drying Temperature (°C) and Buckwheat Bran Flour Concentration (%) on Brightness (CIE *L*-value[a]), Mechanical Strength (Nm), and Susceptibility to Post-Drier Checking (number/m) of Spaghetti

Buckwheat Bran Flour, %	Brightness			Mechanical Strength			Checks		
	40	70	90	40	70	90	40	70	90
0	60.8h[b]	59.1g	56.0f	0.101gh	0.106h	0.092fg	4a	0a	0a
10	40.5e	41.1e	35.5d	0.062bc	0.080ef	0.085f	64b	10a	0a
20	35.3d	35.0d	31.0b	0.054b	0.071de	0.070cd	130c	10a	0a
30	32.5c	32.2c	28.7a	0.034a	0.058bc	0.068cd	162d	14a	0a

[a] *L* values measure black to white (0–100).
[b] Values within the same parameter followed by the same letter are not significantly different ($P < 0.05$).

postdrier checking decreased with increased concentration of buckwheat bran flour and were lowest when spaghetti was dried at low temperature (Table III). The reduction in mechanical strength and in tolerance to postdrier checking can be attributed to physical interference of the gluten matrix by bran particles. High or ultrahigh temperature drying improved the mechanical strength and tolerance to postdrier checking of spaghetti containing buckwheat bran flour. For example, after 2 hr at 80% rh spaghetti containing 10% buckwheat bran dried at low temperature had 4.5× more checks than spaghetti containing 30% buckwheat bran dried at high temperature.

Cooking Quality

Optimum cooking time was shorter for spaghetti that contained buckwheat bran compared with spaghetti that did not contain buckwheat bran (Tables IV and V). Hydration level during extrusion affected optimum cooking time of spaghetti made from semolina but not of spaghetti containing buckwheat bran flour (Table IV). Optimum cooking time was 10.8 min for spaghetti made from semolina hydrated to 29% absorption when compared with 10 min for spaghetti made from semolina hydrated to 30 or 31% absorption. Optimum cooking time seems related to density of extruded spaghetti made from semolina, which was 32.1 g/cm^3 with 29% absorption, compared with 30.1–30.7 g/cm^3 when hydrated to 30–32% absorption (Table II). In addition, the density and optimum cooking time were greater for spaghetti made from semolina than from spaghetti made from semolina containing buckwheat bran flour. The increase in density of extruded spaghetti reflects the SME required for extrusion. Physical disruption of the gluten matrix and overall low density provided a path for water absorption into spaghetti containing buckwheat bran flour, which resulted in shorter cooking times.

The drying temperature by buckwheat bran flour concentration interaction was not significant for optimum cooking time. Optimum cooking time was ≈1.5 min less with spaghetti containing 30% buckwheat bran than with spaghetti without buckwheat bran flour, when averaged over drying temperatures (Table V). When compared with spaghetti dried at 40°C, the optimum cooking time of spaghetti dried at 90°C was 1 min longer for spaghetti without buckwheat flour and 0.5 min longer for spaghetti containing 10% buckwheat bran flour. Drying temperature did not affect optimum cooking time of spaghetti that contained 20 or 30% buckwheat bran.

Hydration level had little effect on cooking loss of spaghetti made from semolina. Cooking loss was similar ≈6.6% for spaghetti made from semolina-buckwheat bran flour hydrated to 29, 30, or 31% absorption (Table IV). However, cooking loss was 7.3% for spaghetti made from semolina-buckwheat bran flour hydrated to 32% absorption.

The drying temperature by buckwheat bran flour concentration interaction was not significant for cooking loss. Cooking loss increased with increased buckwheat bran flour and was greater with spaghetti pasta dried at 40°C than at 90°C (Table V). Disruptions in the protein matrix by bran particles would promote water absorption and facilitate starch granule swelling and rupture. High temperature drying strengthens the gluten matrix, which protects starch granules from rupturing during cooking. Buckwheat bran contains ≈12% soluble dietary fiber (Steadman et al 2001a). These water-soluble components probably leached out of the spaghetti during cooking. Rayas-Duarte et al (1996) also reported increased cooking losses with spaghetti containing dark buckwheat flour.

Cooked firmness of spaghetti made from semolina was greatest when hydrated to 30%, intermediate at 31%, and least when hydrated at 29 or 32% absorption (Table IV). Spaghetti made from semolina-buckwheat bran flour hydrated to 31 or 32% had lower cooked firmness than when hydrated to 29 or 30%. Cooked firmness was least for spaghetti made with 30% buckwheat bran flour that was hydrated to 32%.

The drying temperature by buckwheat bran flour concentration interaction was significant for cooked firmness. At a given concentration, the cooked firmness was similar for spaghetti dried at 40 or 70°C and was greatest when dried at 90°C. Cooked firmness was similar for all concentrations when dried at 70°C; declined

TABLE IV
Effect of Hydration Level on Cooking Quality of Spaghetti Dried at High Temperature

Ingredient	Hydration Level (%)	OPTCK[a] (min)	CKL[b] (%)	CKF[c] (Nm)
Semolina	29	10.8c[d]	5.2b	0.628e
	30	10.0b	4.9a	0.726g
	31	10.0b	5.0ab	0.657ef
	32	10.2bc	4.9a	0.637e
Semolina+BBF[e]	29	9.5a	6.7c	0.588d
	30	9.3a	6.6c	0.579c
	31	9.3a	6.5c	0.549b
	32	9.3a	7.3d	0.471a

[a] Optimum cooking time.
[b] Cooking loss.
[c] Cooked firmness.
[d] Values followed by the same letter in the same column are not significantly different ($P < 0.05$).
[e] Buckwheat bran flour, 30% w/w.

TABLE V
Effect of Drying Temperature (°C) and Buckwheat Bran Flour Concentration on Optimum Cooking Time, Cooking Loss, and Cooked Firmness of Spaghetti

Buckwheat Bran Flour, %	OPTCK[a] (min)			CKL[b] (%)			CKF[c] (Nm)		
	40	70	90	40	70	90	40	70	90
0	10.3c–e[d]	10.8ef	11.3f	6.3b–d	5.4a	5.4a	0.608b–d	0.588bc	0.637d
10	10.0cd	10.5de	10.5de	7.0ef	6.1bc	5.7ab	0.618cd	0.608b–d	0.765e
20	9.7bc	9.8bc	9.7bc	7.3f	7.0ef	6.5c–e	0.588bc	0.579bc	0.843f
30	9.0a	9.3ab	9.3ab	8.3g	6.9d–f	6.1bc	0.530a	0.569ab	0.883f

[a] Optimum cooking time (min).
[b] Cooking loss (%).
[c] Cooked firmness (Nm).
[d] Values within the same cooking parameter followed by the same letter are not significantly different ($P < 0.05$).

only with spaghetti containing 30% buckwheat bran flour when dried at 40°C; it increased with concentration when dried at 90°C. Cooked firmness was greatest for spaghetti dried at 90°C. Ultrahigh temperature drying has been associated with improved cooking quality (Grant et al 1993; Malcolmson et al 1993; Novaro et al 1993). Ultrahigh temperature drying denatures proteins associated with the gluten matrix, which subsequently protects starch granules from rupturing during cooking. Furthermore, ultrahigh temperature drying of pasta reduces water permeability and causes small changes in the packing and arrangement of starch granules, contributing to decreased cooking loss and increased cooked firmness (Vansteelandt and Delcour 1998; Yue et al 1999).

CONCLUSIONS

Extrusion properties were affected by hydration level and by the presence of buckwheat bran flour in the semolina. SME decreased with increased hydration level and with increased buckwheat bran flour concentration. Buckwheat bran flour reduced dough strength by interrupting the gluten matrix. The reduced dough strength was expressed by low SME during extrusion. Low SME transferred to the dough during extrusion resulted in low density of extruded spaghetti.

Cooking properties were affected by hydration level, buckwheat bran flour concentration, and drying temperature. Increased hydration of semolina-buckwheat flour during processing resulted in decreased firmness after cooking. Cooking loss was increased only at 32% hydration of semolina-buckwheat bran flour. Cooking loss generally increased with increased buckwheat bran flour. Low product density, along with high amounts of water-soluble components in buckwheat bran flour (Steadman et al 2001a), probably contributed to the increased cooking loss.

Drying temperature was very important to the overall quality of spaghetti containing buckwheat bran flour. Mechanical strength and tolerance to postdrier stress were greater and cooking loss was lower when spaghetti containing buckwheat bran flour was dried at 70 or 90°C than at 40°C. Cooked firmness was greatest when dried at 90°C, regardless of buckwheat bran flour concentration. Cooked firmness increased with increased concentration of buckwheat bran flour when dried at 90°C. Thus, the best overall quality for spaghetti containing buckwheat bran flour occurred when dried at 90°C. When dried at 90°C, spaghetti containing 30%, w/w, buckwheat bran flour had excellent tolerance to checking and very good mechanical strength and cooking properties.

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