Textural Measurements and Product Quality of Restructured Sweetpotato French Fries

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The objectives of this research were to investigate the applicability of using an alginate–calcium gelling system to produce a French fry-type product using high beta-carotene sweetpotato puree as the main ingredient and to compare four instrumental methods of texture measurement for this product type in relation to sensory textural properties. Sweetpotato puree made with Jewel cultivar sweetpotatoes was restructured using optimized alginate–calcium concentrations. A consumer panel scored sweetpotato fries containing 0.35 g alginate/100 g and 0.5 g $CaSO_4$/100 g highest for appearance, texture, flavor, and overall acceptability. A trained texture profile panel described the product with 15 texture notes. Of these attributes, nine sensory notes describing hardness, mastication shear, cohesiveness, springiness, moistness, and oiliness were highly correlated with some instrumental parameters (r=0.79–0.92) for measuring textural properties. The instrumental methods evaluated were instrumental texture profile analysis, three-point bending force, Kramer shear force, and puncture force. Among these instrumental methods, Kramer shear appeared to be the method of choice because of method's simplicity and high precision (coefficient of variation ≤10%).

Keywords: alginate; calcium; gel; sensory; instrumental methods

Introduction

Sweetpotatoes (SPs) are nutritious but under-utilized vegetables. This is because today's consumer has little free time to spend preparing SP dishes, and there are few processed SP products on the market today. Thus, many consumers are not aware of the unique flavor, texture and nutritional benefits of this vegetable. A major reason for the lack of SP products in the marketplace is that processors have not been able to develop products of consistent texture and flavor. This is because textural properties of SP products are highly dependent on growing conditions and post-harvest handling. To get around this problem, our laboratory has recently developed a restructured baked SP product in which SP puree was texturized using an alginate–calcium gelling system (Truong *et al.*, 1995). Previous attempts to control the textural properties of conventional SP French fries have included partial dehydration (Walter and Hoover, 1986) and temporary modification of tissue pH (Sylvia *et al.*, 1997). While these processes provided some control, the restructuring process described herein appears to have much more potential to overcome the problem of inconsistent texture in French fry-type SP products made directly from SP roots.

Several reports regarding the textural properties of white potato French fries have been published. Lima and Singh (1995) employed the instrumental methods, namely compression, puncture and three-point bending, to describe the texture of the crust and interior of white potato French fries. Du Pont *et al.* (1992) and Choi *et al.* (1999) related sensory properties with objective instrumental methods in order to better understand and quantify the effect of deep-fat frying on textural properties of white potato French fries. Although processes for production of SP French fries have been reported (Walter and Hoover, 1986; Sylvia *et al.*, 1997),

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instrumental and sensory profile methodologies have not been employed to characterize the textural properties.

The purpose of the present research was: (1) to investigate the applicability of using the alginate–calcium gelling system to produce a high quality SP French fry-type product from SP puree; (2) to measure the physical and sensory properties and to relate measured instrumental texture parameters to sensory properties of this product.

Materials and Methods

Preparation of puree

Jewel cultivar SPs were utilized. Cured roots stored at 13–16 °C and 80–90% relative humidity (RH) for 8 months were used. The roots were washed, peeled by immersion in boiling solution (104 °C) of 5.5 g sodium hydroxide/100 sodium hydroxide for 4 min and thoroughly washed in a rotary reel-sprayed washer to remove separated tissue and lye residue. The peeled roots were hand-trimmed and cut into slices of 0.95 cm thick with a slicer (Louis Allis Co., Milwaukee, WI). The SP slices were steam-cooked for 20 min in a Rietz Thermascrew cooker (Rietz Manufacturing Co., Santa Rosa, CA) and comminuted in a hammer mill (model D, Fitzpatrick Co., Chicago, IL) fitted with a 0.62 mm screen. The remainder of the puree was filled into polyethylene bags, frozen and stored at −20 °C until used in product formulations (Truong and Walter, 1994).

Preparation of restructured SP fries

Formulations of restructured SP fries were developed beginning with the optimum formulation previously developed for the restructured baked product (Truong *et al.*, 1995). Dehydrated potato flakes (Nonpareil Processing, Blackfoot, ID) were included to increase product dry matter, resulting in improved product integrity and mouthfeel characteristics. Preliminary experiments allowed us to establish efficacious concentrations of sucrose, dehydrated potato flakes, and tetrasodium pyrophosphate (TSPP; Rhone-Poulenc, Shelton, CT). Concentrations of alginate and calcium sulfate were varied in the nine ingredient combinations prepared. In these formulations, the alginate (type Manugel-DMB, Kelco, Rahway, NJ) was varied from 0.35 to 1.35 g/100 g, and calcium sulfate dihydrate was varied from 0.25 to 0.75 g/100 g (**Table 1**).

The process flow for restructured SP French fries is shown in **Fig. 1**. For each formulation (**Table 1**), the ingredients were mixed in an electronic chopper (Model UMC5, Stephan Co., West Germany) at 1800 rpm. Between each ingredient addition, the chopper lid was secured and the ingredients were mixed for 1 min. The mixing step was repeated with each ingredient addition in order to thoroughly disperse ingredients and ensure that a homogenous blend was obtained. When all ingredients had been added and mixed, the blended mixture was immediately extruded into 5.5 cm diameter sausage casings, clipped to form rolls of about 10 cm in length, and the ends fastened. The rolls were held for 24 h at 4 °C, cut into 0.9 × 0.9 × 9.0 cm strips, and stored at −20 °C until cooked.

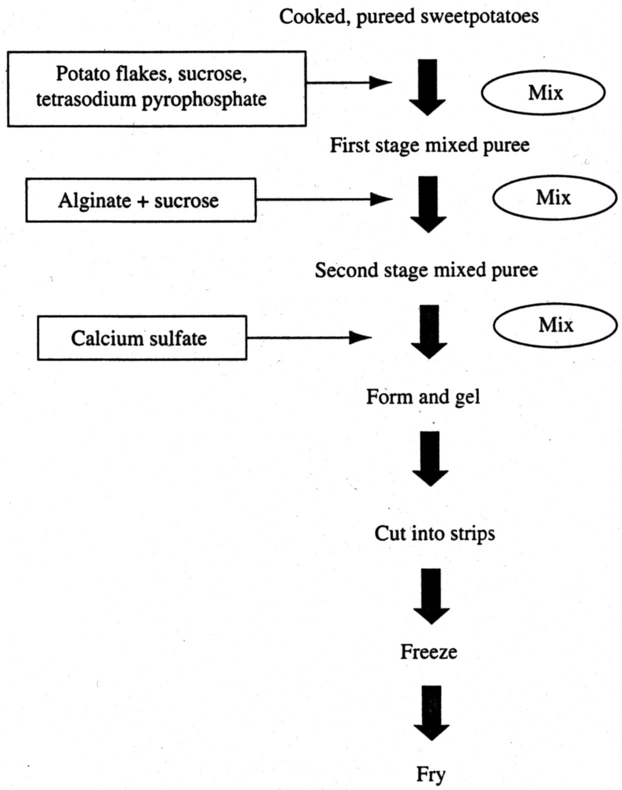

Fig. 1 Flow sheet for preparation of the restructured sweetpotato French fry product

Table 1 Ingredient concentrations (g/100 g) for restructured sweetpotato fries

Formulation no.	Alginate	$CaSO_4$	Sweetpotato puree	Potato flakes	Sucrose	Water	TSPP
1	1.35	0.50	85.0	7.0	4.0	2.0	0.18
2	1.10	0.63	85.1	7.0	4.0	2.0	0.18
3	1.10	0.38	85.4	7.0	4.0	2.0	0.18
4	0.95	0.25	85.6	7.0	4.0	2.0	0.18
5	0.85	0.75	85.2	7.0	4.0	2.0	0.18
6	0.85	0.50	85.5	7.0	4.0	2.0	0.18
7	0.60	0.63	85.6	7.0	4.0	2.0	0.18
8	0.60	0.38	85.9	7.0	4.0	2.0	0.18
9	0.35	0.50	86.0	7.0	4.0	2.0	0.18

Preparation of fries from whole roots/tubers

Whole SP roots were hand peeled, cut into strips as described above for restructured SP French fries and cooked.

A commercial frozen white potato French fry product manufactured by Ore-Ida (Kameth, ID) was purchased from a local grocery store. Frozen strips of this product were fried in the same soybean oil as was used for SP samples.

Sensory evaluation

Untrained panel. Frozen strips were fried in soybean oil at 160 °C for 1.5 min. Warm strips kept in an oven at 60 °C were served to panelists within 15 min after frying. A total of ten samples, including nine formulations and a control, of fried, fresh-cut SP strips were evaluated. Samples were subjected to a sensory acceptability test by a 30-member, untrained panel consisting of faculty, staff, and graduate students from the Department of Food Science at NC State University. At each sitting, panelists were asked to evaluate four samples presented a random order for appearance, texture, taste, and overall acceptability on a nine-point hedonic scale (9=like extremely, 5=neither like nor dislike, 1=dislike extremely). All panel sessions were conducted in sensory panel booths under fluorescent light.

Texture profile panel. Sensory texture profiles of the nine formulations were assessed by a six-member panel previously trained in profile methods of descriptive texture analysis (Brandt *et al.*, 1963) for various foods, including SP. The texture notes were established using earlier reports (Walter, 1987) as the starting point. Panelists following established guidelines (Civille and Szczesniak, 1973) developed a texture note profile (**Table 2**) for the SP fry product. Texture note development was accomplished during two 3-h training sessions on two consecutive days on the SP French fry product. Scores for texture notes were based on a 14-point descriptive intensity scale (Caul, 1957) which was converted to a 1–14 numerical scale for statistical analysis, with a score of 1=not detectable and a score of 14=extremely intense. At each session, panelists evaluated five coded samples in random order. A sample of strips made from SP roots prepared as described above was used as a control and as a reference standard.

Physical measurements

Textural properties of the fried strips were evaluated at 55 °C using a TA.XT2 Texture Analyser (Texture Technologies Corp., Scarsdale, NY/Stable Microsystems, Surrey, U.K.) fitted with the appropriate test accessory. Data collection and analysis were accomplished electronically by the XTRAD Dimension software of the TA.XT2 analyser. The instrumental methods are described below:

Puncture. A cylindrical flat-end punch (1 mm diameter probe) was used. The test speed was 1.6 mm/s, and the punch traveled 6 mm into the fried strips. The peak force and area under the force–deformation curve were obtained for 15 replicates per sample.

Bending. A three-point bending accessory was used. Fried strips were placed on two vertical supporting bars with 45 mm apart. A third bar attached to the crosshead of the instrument was driven perpendicular to the sample at speed of 1.6 mm/s, with 8 mm travel. The peak force and area under the force–deformation curve were obtained for 15 replicates per sample.

Table 2 Texture profile panel notes[a] for restructured French fried sweetpotatoes[a]

1. Initial: Visual or tactile as indicated by definition:
   Surface smoothness (Ismooth)—Degree to which the surface of the fries is free from bumps, particles or a blistered appearance
   Flexibility (Iflexi)—Degree to which the samples bend downward without breaking when ends are brought together, holding each end with fingers, into an upside down U shape
   Springiness (Ispringi)—Degree to which the sample recovers its original shape when compressed with the lips before rupture.
2. First bite: Using the front teeth, bite into the sample approximately 1 cm from the end and evaluate for:
   Hardness (Bihard)—Amount of force necessary to bring the teeth together completely
   Crust (Bicrust)—Degree to which the crust can be perceived between the front teeth after squeezing out the interior of the sample with the teeth in small 'chipmunk-style' bites
   Density (Bidens)—Lack of a cellular, airy structure
3. Mastication: Chew a fried strip and evaluate for:
   Chewiness (Maschew)—Number of chews required to prepare the sample for swallowing when chewing at a constant rate of one chew per second
   Cohesiveness (Mascohe)—Cohesiveness of mass at 8–10 chews (i.e. degree to which the mass hold together at 8–10 chews)
   Oiliness (Masoil)—Degree to which the sample feels oily
   Moistness (Masmoist)—Moisture present—Degree to which panelist senses the amount of moisture present in the sample throughout mastication
   Adhesiveness (Masadhe)—Degree to which the sample adheres to any of the mouth surfaces such as teeth, lips, gums, palate.
   Shear (Mashear)—Degree to which the sample cuts 'cleanly' into pieces while chewing
   Compression (Mascomp)—Degree to which the sample deforms and mashes while chewing.
4. Residual: Immediately after swallowing evaluate for:
   Particles (Swapart)—Amount of potato particles remaining in the mouth.
   Oily mouth coating (Swaoil)—Amount of oily residue left in the mouth.

[a]Abbreviations in parentheses are used in accompanying tables to identify textural attributes.

Kramer shear. Eight fried strips were placed across the bottom of a five-blade Kramer shear cell. Blades were driven downward at speed of 1.6 mm/s. The peak force and area under the force–deformation curve were obtained. Three replicate analyses were performed for each sample.

Instrumental texture profile analysis (ITPA). Fried strips were cut into 9 mm cubes and compressed between two parallel plates for two cycles. The test conditions were: pre-test speed, 5 mm/s; test speed, 1.6 mm/s; post-test speed, 1.6 mm/s; time between two cycles, 5 s; and degree of compression, 75%. ITPA parameters were calculated as described by Bourne (1978).

Statistical analysis
All analyses were performed using the General Linear Model and Pearson Correlation Coefficient procedures of the Statistical Analysis System (SAS, 1988).

Results and Discussion

Product formulations
The puree used in this research had the following composition (fresh weight basis): dry matter, 20.57 g/100 g; alcohol-insoluble solids (starch, cell wall components, etc.), 8.70 g/100 g; sugars, 11.87 g/100 g. Composition of the nine different formulations is provided in **Table 1**. Concentrations of alginate and calcium sulfate were the two formulation variables. The major formulation difference between the restructured French fry product and the previously developed restructured baked SP product (Truong *et al.*, 1995) was that we increased product dry matter functionality by including dehydrated white potato.
The order of mixing of ingredients (**Fig. 1**) had a significant impact on product quality. Because SP have from 5 to 10 mg of calcium in 100 g, it was essential that TSPP be added first to complex this endogenous calcium. If this was not done, gel formation was incomplete and poor texture resulted.

Sensory evaluation

Untrained panel. Mean sensory scores for the SP fries are presented in **Table 3**. There were no statistically significant differences ($P \leq 0.05$) in scores for appearance, texture, taste, and overall acceptability among the formulations. Because there was so much variability in these scores, it was not possible to identify the optimum formulation with statistical significance. Thus, formulation #9 was chosen as superior since it had the highest numerical overall score of 7. According to the Hedonic scale, this formulation was rated by panelists as 'like moderately'. It is interesting to note that SP strips of the same size as the restructured product cut from stored roots and fried under the same conditions were rated by the panelists as being slightly less than 'neither like nor dislike' (4.8).

Texture profile panel. The trained texture profile panel identified 15 textural attributes for this product (**Table 2**) which were grouped into the following categories: (1) initial (surface smoothness, flexibility and springiness); (2) first bite (hardness, crust, and density); and (3) mastication (chewiness, cohesiveness, oiliness, moistness, adhesiveness shear, and compression). The formulations are arranged in decreasing order of alginate concentration, and, where alginate concentrations are identical, the calcium sulfate concentration is arranged in order of decreasing concentration (**Table 1**). For example, for formulations #2 and #3, the alginate concentration is 1.10 g/100 g for both, while the calcium sulfate concentration is 0.63 g/100 g for formulation #2 and 0.38 g/100 g for formulation #3.
From the trained profile panel data (**Table 4**), no apparent trend resulted for any of the attributes as a result of declining alginate concentration. This observation is not surprising in view of the fact that the calcium concentration also plays a significant role in alginate gelation affecting the product textural properties. However, it is possible to examine formulations in which the alginate concentration is constant, while the calcium concentrations vary. In formulations #2 and #3, formulations #5 and #6, and formulations #7 and #8, this is the case (**Table 1**). The data are also arranged so that, for each pair the calcium concentration is greater for the first member of the pair. Moreover, both alginate

Table 3 Consumer acceptability scores for restructured sweetpotato fries and fresh-cut sweetpotato fries[a]

Formulation no.	Appearance	Texture	Taste	Overall
1	6.6	5.7	5.9	5.7
2	7.1	6.0	5.8	5.8
3	7.1	6.2	6.5	6.2
4	6.5	6.0	6.5	6.1
5	7.2	6.2	5.9	6.1
6	6.9	6.1	6.1	6.1
7	7.2	6.2	6.2	6.3
8	7.0	6.1	6.4	6.2
9	7.0	7.0	7.1	7.0
Fresh-cut strips	4.9	4.9	5.4	4.8

[a]Where formulations are not separated by a space, alginate concentrations are identical.
See **Table 1** for formulation composition. Hedonic scores: 9=like extremely, 7=like moderabely, 5=neither like nor dislike, 3=dislike moderately, 2=dislike extremely.

Table 4 Mean values of scores from trained texture profile panel[a]

Formulation no.	Ismooth	Iflexi	Ispringi	Bihard	Bicrust	Bidens	Maschew	Maschohe	Masoil	Masmoist	Masadhe	Mashear	Mascomp	Swapart	Swaoil
1	10.7	8.0	3.8	8.2	6.0	8.5	22.3	5.7	4.7	6.5	3.3	8.7	7.3	6.3	4.3
2	11.2	8.0	4.2	8.4	5.2	9.0	21.8	5.6	4.2	6.2	3.4	9.0	7.0	5.8	3.8
3	10.5	9.5	3.0	6.8	5.7	7.2	22.3	7.0	5.3	7.8	5.0	6.8	9.0	5.5	4.8
4	9.8	13.0	1.0	5.8	7.5	4.3	21.8	8.8	8.8	9.2	8.7	4.3	10.3	8.7	7.7
5	11.4	8.6	4.8	7.4	4.8	8.2	21.2	6.6	4.8	6.8	3.0	8.4	7.0	6.4	4.2
6	11.0	7.7	3.5	6.7	4.8	7.7	22.0	5.8	5.0	7.0	3.7	7.8	8.0	6.2	4.0
7	10.6	6.6	3.6	5.8	4.4	6.2	21.4	8.4	5.6	8.4	4.2	5.8	9.0	5.6	4.4
8	9.0	11.6	2.0	6.0	5.6	6.4	20.2	8.4	6.0	8.8	4.6	4.6	9.8	5.6	5.6
9	9.0	10.8	2.2	5.4	5.2	5.4	19.8	9.0	6.2	9.8	4.4	4.4	10.6	5.2	5.8
Ore-Ida	10.0	5.6	2.2	6.2	6.2	6.6	20.0	5.4	7.4	8.0	4.8	6.0	9.0	7.8	5.8

[a]Scoring scale runs from 1=not detectable to 14=extremely intense. For textural attribute definitions, see **Table 2**. Where formulations are not separated by a space, alginate concentrations are identical. See **Table 1** for formulation composition.

and calcium decrease for each succeeding pair. The data indicate that, for all three pairs, the intensity of initial springiness and mastication shear decrease as calcium decreases, indicating a less elastic gel structure (**Table 4**). If instead one considers the formulations in which the calcium concentration is held constant while alginate concentrations decrease (formulations #2 and #7, formulations #1, #5, and #9, and formulations #3 and #8), different trends are observed (**Table 1**). It appears that the intensities of first bite hardness and mastication moistness decline with decreasing alginate concentration, while the intensity of mastication cohesiveness increases with decreasing alginate. These results could also be explained in terms of a soft and more deformable (elastic) gel structure. A soft gel would result in a less smooth matrix perceived as being more adhesive to mouth surfaces.

Although the untrained sensory panel scored formulation #9 as the most preferred numerically, there was no distinct scoring pattern for this formulation relative to the others by the trained texture profile panel (**Table 4**). That is, formulation #9 had similar scores to one or more of the formulations for each attribute. In comparison to the Ore-Ida French fry, formulation #9 had much higher initial flexibility, mastication cohesiveness and mastication moistness, much lower particles during swallowing.

Physical measurements

Three types of instrumental analyses were performed on the restructured French fries made from each of the nine formulations and a commercial white potato French fry product. The values for peak force and coefficient of variation for the puncture force test, three-point bending test, and Kramer shear test are presented in **Table 5**. As was the case for the results from the texture profile panel, for the formulation pairs with identical alginate concentrations, decreasing gel strength was observed with decreasing calcium concentration. This was true for the peak force measured by puncture, three-point bending and Kramer shear test. In addition, the same trend was obtained if one compares the results from those sets of formulations in which the calcium concentration is held constant and the alginate concentration is decreased (i.e. formulations #2 and #7, formulations #1, #5, and #9, and formulations #3 and #8). If one compares the results from the Ore-Ida fries to those of formulation #9 (the optimum formulation), it is obvious that the force required in all three tests was much higher for the Ore-Ida product than for formulation #9, and indeed for all of the formulations. This is not surprising in view of the fact that the natural structure of potato tuber is intact for the Ore-Ida product, while all of restructured SP fries are held together by an alginate–calcium gel.

Furthermore, it should be noted that the peak force of Kramer shear test had by far the lowest coefficient of variation among the instrumental procedures we employed (**Table 8**). Results on area under the force–deformation curve of puncture and three-point bending

Table 5 Mean values and coefficients of variation (CV) for peak force of puncture, three-point bending, and Kramer shear test for sweetpotato and Ore-Ida fries[a]

Formulation no.	Puncture test (mN)	CV (%)	Three-point bending test (mN)	CV (%)	Kramer shear test (mN)	CV (%)
1	516.5	20.7	321.0	15.5	175.8	6.3
2	564.2	16.4	311.7	20.4	170.3	3.0
3	436.0	34.1	257.4	19.3	111.1	3.5
4	254.6	38.4	133.6	34.7	68.4	4.7
5	554.9	16.9	356.6	13.3	174.0	3.5
6	468.2	13.0	275.3	13.1	134.1	4.1
7	404.7	21.2	297.5	11.0	104.0	2.3
8	359.8	29.7	177.3	21.1	70.8	5.4
9	307.2	28.6	177.9	17.1	67.3	7.6
Ore-Ida	760.5	38.2	699.5	24.8	219.2	3.8

[a]Where formulations are not separated by a space, alginate concentrations are identical. See **Table 1** for formulation composition.

Table 6 Mean values and coefficients of variation (CV) for variables in ITPA for restructured sweetpotato and Ore-Ida fries[a]

		Hardness (N)				Gumminess (N)		
Formulation No.	Springiness	C.V. (%)		C.V. (%)	Cohesiveness	C.V. (%)		C.V. (%)
1	0.3	10.4	18.6	21.4	0.2	4.2	4.1	24.9
2	0.3	20.1	20.8	28.5	0.2	5.4	4.6	30.8
3	0.3	14.3	14.6	39.6	0.3	8.3	3.7	39.5
4	0.2	16.9	3.3	96.8	0.3	9.1	1.0	54.0
5	0.3	15.9	22.7	29.7	0.2	10.8	4.8	38.2
6	0.3	11.2	15.5	31.4	0.2	6.6	3.4	34.8
7	0.2	20.6	11.4	31.9	0.2	5.2	2.4	36.5
8	0.2	14.9	6.2	41.6	0.2	6.8	1.4	41.4
9	0.2	20.0	7.9	49.9	0.2	8.5	1.9	54.1
Ore-Ida	0.3	37.4	13.1	50.2	0.2	19.0	2.9	54.0

[a]Where formulations are not separated by a space, alginate concentrations are identical. See **Table 1** for formulation composition.

test also had large coefficients of variation (data not shown). On the other hand, DuPont *et al.* (1992), investigating the effect of cooking time on white potato French fry properties, employed two pendulum techniques and a three-point bending method to characterize textural properties. They found that a portable instrumented pendulum was best able to differentiate between samples.

Examination of the data from the imitative ITPA indicated that only for the hardness parameter was there a definitive relationship exhibited between constant alginate/variable calcium concentrations and constant calcium/variable alginate concentrations, as was noted for some of the other tests (**Table 6**). That is, hardness declined as alginate or calcium concentrations declined, again indicating decreased gel strength. In addition, gumminess also appeared to be affected in the same manner as hardness, but the coefficients of variability were so great that this relationship is not as certain. The ITPA parameters of the product from Ore-Ida were not noticeably different from one or more of the SP formulations within each parameter. The Ore-Ida product did, however, tend to be harder than formulation #9, the formulation scored highest by the untrained panel.

In order to determine if any of the instrumental parameters correlated with the texture profile panel scores, we conducted a Pierson product–moment correlation analysis. Nine sensory texture notes spanning the three classes of texture attributes describing hardness, mastication shear, cohesiveness, springiness, moistness, and oiliness were highly correlated with instrumental parameters (r=0.79–0.92; **Table 7**). To ascertain which of the instrumental methods gave the better results, we examined the data for the instrumental *vs.* sensory correlation (**Table 7**) and the coefficients of variation among the instrumental methods (**Tables 5** and **6**). Considering both sets of data, it appeared that, of the four instrumental methods, the Kramer shear test gave excellent correlation with seven sensory texture attributes, high precision (coefficient of variance $\leq$10%), and was among the easiest to perform. Thus, the Kramer shear force would appear to be the method of choice to monitor product quality.

Conclusions

This research has demonstrated that restructured SP fries with consistent texture and consumer acceptability can be made from SP puree using the alginate–calcium gelling system. The Kramer shear method is recommended for texture measurement of this product type.

Table 7 Significant correlation coefficients between instrumental and sensory texture parameters of noncoated sweetpotato fries

	Instrumental methods						
	Texture profile analysis				Other methods		
Sensory attribute	Hardness	Cohesiveness	Springiness	Chewiness	Punch test	Three-point bending	Kramer shear
1. *Initial*							
Springiness	0.83					0.81	0.80
2. *First Bite*							
Hardness	0.85			0.88	0.84	0.80	0.88
Crust		0.849					
Density	0.92			0.92	0.92	0.88	0.90
3. *Mastication*							
Cohesiveness	−0.88		−0.84	−0.90	−0.88	−0.81	−0.89
Oiliness	−0.82			−0.80	−0.83	−0.80	
Moistness	−0.92			−0.90	−0.91	−0.85	−0.92
Shear	0.92		0.82	0.89	0.89	0.82	0.91
Compression	−0.91			−0.85	−0.88	−0.81	−0.90

Table 8 Reproducibility of the instrumental methods

Method/parameter	CV (%)
(1) *Kramer shear*	
Peak force	1.92–9.98
Area	4.42–19.34
(2) *Punch test*	
Peak force	13.01–38.36
Area	22.14–59.82
(3) *Three-point bending*	
Peak force	10.95–24.89
Area	15.36–31.26
(4) *TPA*	
Hardness	19.90–41.58
Cohesiveness	4.16–12.42
Springiness	10.35–20.60
Chewiness	17.50–61.50

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