Lebensm.-Wiss. u.-Technol., 35, 209–215 (2002)

Textural Measurements and Product Quality of Restructured Sweetpotato French Fries

W. M. Walter Jr*, V. D. Truong and K. R. Espinel

W. M. Walter Jr: U. S. Department of Agriculture, Agricultural Research Service, North Carolina State University, Raleigh, NC 27695-7624 (U.S.A.)
V. D. Truong: North Carolina Agricultural Research Service, North Carolina State University, Department of Food Science, Raleigh, NC 27695-7624 (U.S.A.)
K. R. Espinel: Kraft Foods Inc., Tarrytown, NY (U.S.A.)
(Received December 13, 1999; accepted September 21, 2001)

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),

*To whom correspondence should be addressed. Tel.: +919 515 2979; Fax: +919 856 4361; E-mail: wmwalter@ncsu.edu.
Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or North Carolina Agricultural Research Service, nor does it imply approval to the exclusion of other products that may be suitable.

0023-6438/02/$35.00
doi:10.1006/fstl.2001.0840

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.

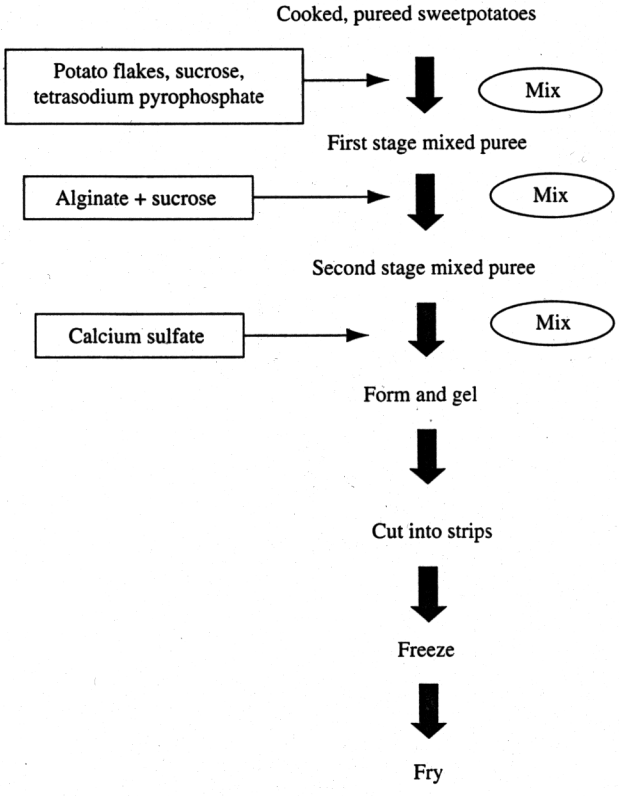

Fig. 1 Flow sheet for preparation of the restructured sweetpotato French fry product

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.