Process Effect on Couscous Quality[1]

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ABSTRACT

Commercial and traditional homemade couscous are both produced by the agglomeration process. Each couscous granule represents an aggregate of several semolina particles. Couscous manufactured by this process lacks a definite uniform shape and size. The objective of this study was to produce couscous with more uniform shape and size using extrusion technology. High-temperature short-time twin-screw and low-temperature single-screw extruders were utilized. The extruded and agglomerated couscous were evaluated for color, water absorption index, water solubility index, degree of starch gelatinization, cooking quality, and sensory attributes. The twin-screw-extruded couscous was characterized by its shape and size uniformity, its intense yellow color, and its high degree of starch gelatinization. This product also showed significantly higher water absorption, shorter rehydration and cooking times, and better appearance, flavor and overall acceptability than that of the agglomerated couscous (commercial and homemade). The single-screw extruded couscous was also uniformly sized but had excessively long rehydration and cooking times due to its dense and compact texture. In addition to its poor cooking quality, this product showed the highest water solubility index and was poorly rated for most of the sensory attributes tested.

Couscous is one of the most ancient alimentary pastes developed by the native inhabitants (Berbers) of North Africa. It has traditionally been prepared by mixing semolina and water (with 2% salt) in a large wooden dish and rolling the two ingredients by hand until agglomeration of couscous granules resulted in granule formation. The well-shaped and uniformly sized (by sieving) couscous granules are then steamed and sun-dried. It was not until the mid 1970's that fully automated couscous production lines started in North Africa, and later in other parts of the world, like France, Italy, Greece, and more recently in the United States.

The industrial processing stages are: mixing-agglomeration, detaching, sifting, steam cooking, drying, cooling, and packaging (Anonymous 1981). In the mixing-agglomeration stage, semolina and water are blended with a high-speed mixer until optimum agglomeration into couscous granules is achieved. The moist agglomerates are then discharged into the detacher to separate the entangled couscous granules. From the detacher, couscous is conveyed to a wet-sifting process to remove the oversized agglomerates and fine particles. After sizing, couscous is steam cooked, dried, and graded into the desired granulations. Couscous quality can be assessed on the basis of several characteristics: color, shape, and size uniformity; rehydration and cooking times; cooked weight; stickiness; and mouthfeel. Guezlane et al (1986) reported that homemade or traditional couscous had a better shape and size uniformity and smoother surface than did commercial agglomerated couscous. Kaup and Walker (1986) found that sensory panelists preferred the color of commercial couscous and the shape of the homemade product.

The objective of this research was to investigate the possibility of using extrusion technology (single- and twin-screw extruders) to produce couscous with more uniform shape and size and with sensory attributes that are acceptable to the consumer.

MATERIALS AND METHODS

Raw Material

Commercial semolina (Durakota) was provided by North Dakota State Mill (Grand Forks, ND). Semolina protein and ash were determined according to standard methods (AACC 1995). Starch damage was determined by the Farrand method (1964). Mixograph evaluation of semolina was determined according to the standard method (AACC 1995) with modifications. The semolina samples were mixed for 8 min at constant water absorption of 5.8 ml, using a spring setting of 8. The mixograms were scored by comparing them to reference mixograms (Dick and Young 1988). The number of specks in semolina was determined by counting the number of visible specks in three different 1 sq. in. areas. Results are expressed as the number of specks per 10 sq. in.

Homemade Couscous Preparation

Approximately 100 ml of water with 2% salt was added to 250 g of semolina in a large aluminum pan and thoroughly mixed and rolled by hand until agglomeration of semolina particles resulted in couscous granule formation. The couscous was sieved through a set of two sieves (1,400 and 1,900 µm mesh openings). The well-shaped and uniformly sized couscous granules were steamed in a couscous maker for 10 min. The steamed couscous was laid out on a cloth sheet and dried at room temperature for 48 hr. After drying, couscous was sieved through a standard testing sieve (1,700 µm mesh opening) to remove any large agglomerates formed during the steaming process.

Single-Screw Pasta Extrusion

Couscous was processed on a DeMaco continuous extruder (DeFrancisci Machine, Co., Brooklyn, NJ) with a capacity of 10 kg/hr. Semolina (1,000 g) was mixed with an appropriate amount of distilled water at 40°C to obtain a dough moisture of 33%. Water was added slowly while mixing at slow speed (speed setting 1) in a Hobart mixer (model C100, Hobart Manufacturing Co., Troy, OH). After complete addition of water, the sample was mixed at high speed (speed setting 3) for 4 min and transferred to the DeMaco mixer. Dough was extruded through a vermicelli die with 1.19-mm opening. A rotating cutter equipped with two knives was used to produce the desired couscous granulation by setting the speed of the cutter. Barrel temperature was 45°C; screw speed was 20 rpm; and vacuum pressure was 457 mm Hg.

The extruded couscous was steamed for 10 min in a couscous steamer and dried at high temperature, using the drying conditions shown in Figure 1. In the first stage of the drying cycle, the temperature and the relative humidity were increased in the first hour from the starting conditions of 30°C and 78% rh to 56°C and 83% rh, respectively. In the second stage, the temperature was gradually increased to the final temperature of 73°C, while the

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relative humidity was gradually decreased to 72%. These conditions were maintained for 9.5 hr, followed by a cool-down period of 2 hr, during which the temperature and relative humidity were lowered to 30°C and 47%, respectively.

Twin-Screw Extrusion with Cooker

A corotating intermeshing twin-screw extruder (model TX-52, Wenger Manufacturing, Inc. Sabetha, KS) was used to produce couscous. The extruder included a preconditioner, a barrel with nine sections, and a vermicelli die. The barrel was divided into six cooking zones, a venting zone, or vacuum (10 in. Hg) to remove gaseous products from the semolina and water mixture, a conical barrel section at the discharge of the two corotating screws, and a die section. The extrusion conditions and screw configuration used were as described in Donnelly et al (1994). The extruded couscous was dried at high temperature as shown in Figure 1.

Color Analysis

Couscous color was measured according to the standard method (AACC 1995), using a Gardner color difference meter (model XL-10, Pacific Scientific, Gardner Laboratory Division, Bethesda, MD). Hunter Lab yellowness (*+b* value) and brightness (*L* value) were determined on couscous. Carotenoid pigments were determined according to the standard method (AACC 1995).

Bulk Density

Bulk density of the couscous samples was determined by filling a 500-ml graduated cylinder with 250 g of couscous. Measurements were expressed as the ratio of couscous weight per unit volume.

Degree of Starch Gelatinization

Degree of starch gelatinization in couscous was measured by both enzymatic and calorimetric methods. The enzymatic method described by Shetty et al (1974) was used with some modifications. Glucoamylase from *Rhizopus delemar* (Sigma Chemical Co., St. Louis, MO), with total glucoamylase activity of 150 IU, was used for each sample. The method involves the enzymatic digestion of the gelatinized starch granules by glucoamylase to glucose, and the subsequent determination of the glucose by the glucose oxidase-peroxidase method. The brown color after reaction was measured at 400 nm, using a UV/VIS spectrophotometer (Perkin Elmer Lambda 3B, Norwalk, CT).

Calorimetry was the other method used to measure the degree of starch gelatinization. This method is based on the principle that heat either is absorbed or liberated when a material undergoes a change in physical state, such as melting or transition from one crystalline form to another, or when a material reacts chemically. Differential scanning calorimetry (DSC) (model DSC7, Perkin Elmer, Norwalk, CT) was used to measure the enthalpy of transition or heat of gelatinization (ΔH) of the starch in the samples, as described by Gomez and Aguilera (1984) with some modifications. Samples of 9 mg each were mixed with 18 mg of water (1:2 sample-to-water ratio) in DSC pans; the suspension was heated from 30 to 150°C at 10°C/min in an hermetically sealed sample pan. The instrument was calibrated with indium and ΔH calculated from the peak area of the thermogram. The starch gelatinization in couscous was compared to the ΔH of the raw untreated and extruded samples and calculated as: gelatinized starch (%) = $[1 - (\Delta H \text{ extruded}/ \Delta H \text{ raw})] \times 100$.

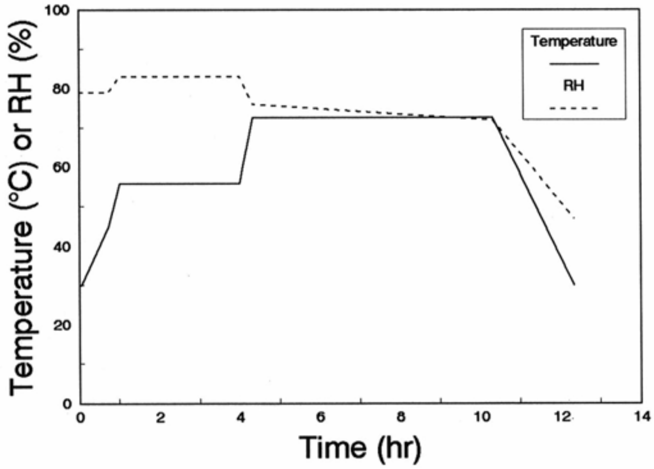

Fig. 1. Buhler high-temperature drying cycle.

Physicochemical and Cooking Properties

Couscous particle size distribution was determined using a Ro-Tap testing shaker (W.S. Tyler Co., Cleveland, OH). A 100-g sample was sifted for 1 min on U.S. standard sieves No. 14, 16, 18, 20, and 30. The percentage of each fraction was calculated by weighing the overs remaining on each sieve. Couscous water absorption index (WAI) and couscous water solubility index (WSI) were determined according to the method of Anderson et al (1969). Couscous cooking properties (cooked weight, rehydration and cooking times, and stickiness) were determined as reported by Debbouz et al (1994).

Scanning Electron Microscopy

Scanning electron micrographs were prepared at the SEM laboratory, NDSU, Fargo, ND. Samples of dry couscous were adhered to specimen stubs with double-stick tape and sputter-coated with gold-palladium in a Balzas SCD-030. The surface of the sample was scanned, using a JEOL JSM-35 electron microscope, and representative areas were photographed at 12× magnification.

Sensory Evaluation

A 25-member panel was selected among students and staff of the Cereal Science and Food Technology Department, NDSU, Fargo, ND, to conduct the sensory evaluation of cooked couscous. Commercial agglomerated, homemade, and extruded couscous samples were evaluated for their cooked sensory attributes (appearance, mouthfeel, flavor, and overall acceptability), using a nine-point hedonic scale (1 = dislike extremely, 9 = like extremely). Before evaluation, optimum sensory attributes were described and explained to the panelists by the principal author (Debbouz). Sensory evaluation sessions were conducted in the morning, and performed in partitioned booths with overhead fluorescent lighting. Three tablespoons of each cooked couscous sample cooled to ≈45°C and coded with three-digit random numbers, were presented with a scorecard to each panelist.

TABLE I
Physicochemical Characteristics of Extruded and Agglomerated Couscous[a]

Sample	Color *L*	Color *+b*	Carotenoid Pigments (ppm)	Bulk Density (g/cm³)	WAI[b] (g/g)	WSI[c] (%)
Agglomerated						
Homemade	71.28a	30.70b	4.53a	0.604c	4.02b	4.92b
Commercial	68.87b	27.07d	4.00a	0.790b	4.12b	4.60bc
Extruded						
HTST twin-screw[d]	63.60c	31.75a	4.14a	0.812b	5.07a	4.35c
LT single-screw[e]	62.50d	28.45c	4.31a	0.904a	3.70b	5.75a
LSD (0.05)[f]	0.89	1.03	0.58	0.026	0.47	0.49

[a] Means followed by the same letter in each column are not significantly different ($\alpha = 0.05$) by Duncan's multiple range test. Results are means of duplicate analysis.
[b] Water absorption index, results expressed as weigt of gel/gram of dry sample.
[c] Water solubility index, results expressed as % of dry solids in the supernatant.
[d] High-temperature short-time twin-screw extruder.
[e] Low-temperature single-screw pasta extruder.
[f] Least significant difference, comparison of two means.

Statistical Analysis

The data were statistically analyzed using the Statistical Analysis System (SAS Institute Inc., version 6, Cary, NC). Analysis of variance and Duncan's multiple range tests were used for mean comparisons.

RESULTS AND DISCUSSION

The commercial semolina was evaluated for some of its physicochemical characteristics. Protein content, ash, and starch damage were 13.1, 0.60, and 12.6%, respectively. Mixogram score and speck count were 5, and 47 specks/10 sq. in., respectively. These results indicated that the semolina was of intermediate gluten strength and had an acceptable level of starch damage and protein for couscous production.

The physical and chemical characteristics of the single- and twin-screw extruded and agglomerated couscous are presented in Table I. Couscous color was measured by light reflectance using the Hunter Lab color space, and by pigment extraction.

The agglomerated couscous had significantly higher brightness values (L) than the extruded couscous. As shown in Figure 2 C and D, each agglomerated couscous granule represents an aggregate of semolina particles compared to the more uniform granules of the extruded couscous (Figure 2 A and B). The large number of particles reflecting light in the agglomerated couscous may have caused the brightness difference between the products made by extrusion and agglomeration. Homemade agglomerated couscous had the finest granulation (52.8% through U.S. standard sieve No. 18, 1-mm mesh opening) compared to commercial agglomerated (5.3%), twin-screw and single-screw extruded couscous (1.1 and 0.8% respectively).

The twin-screw extrusion cooked couscous showed significantly higher yellowness value ($+b$) than the agglomerated or the single-screw extruded couscous. Marty (1986) reported that high barrel temperature and pressure of the extrusion cooker induce a *cis-trans* isomerization reaction of the carotenoid pigments with the formation of compounds that have the same spectral characteristics as the 15, *cis*-β carotene. He isolated and identified 26 colored thermal degradation compounds derived from *trans*-β carotene. This is perhaps the cause of the $+b$ value increase because the carotenoid pigment content of the extrusion-cooked couscous was not significantly different from the other three products.

Traditionally, couscous is rehydrated with water, steamed, and served with a warm vegetable sauce. The capacity of couscous to rapidly absorb the sauce and maintain its firmness is considered a good quality attribute. Water absorption index (WAI) was used to assess this quality factor. Extrusion-cooked couscous had significantly higher WAI than did the agglomerated or the single-screw extruded couscous (Table I). This may be attributed in part to the high proportion of gelatinized starch found in the extrusion-cooked couscous (Table II). Peplinski and Pfeifer (1970) reported that the WAI of corn and sorghum grits increased as temper moisture level, retention time in the autoclave, and steam-cooking temperature increased. They related this increase in WAI to greater starch gelatinization of the grits. Debbouz (1992) also found a high correlation ($r = 0.90$) between WAI and starch gelatinization.

Water solubility index (WSI) expresses the percentage of dry matter recovered after the supernatant is evaporated from the water absorption determination. The amount of soluble materials leached out during cooking may have a detrimental effect on couscous stickiness, especially with the new quick preparation method where couscous is soaked in hot water compared to the traditional rehydration and steaming method. No significant difference in WSI was found between the two agglomerated products and between the extrusion cooked and commercial couscous.

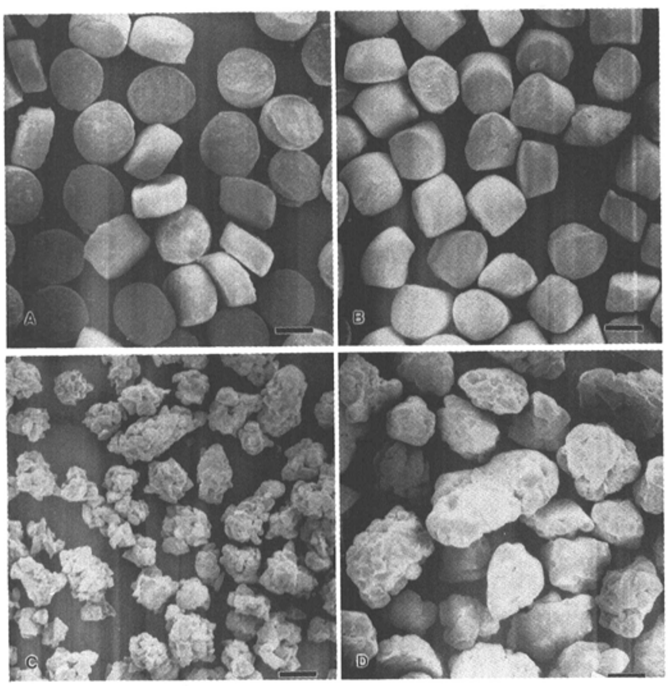

Fig. 2. Scanning electron micrographs (12×) showing particle size and shape uniformity of **A)** twin-screw extruded couscous, **B)** single-screw extruded couscous, **C)** homemade agglomerated couscous, and **D)** commercial agglomerated couscous. Bar = 830 μm.

TABLE II
Couscous Cooking Quality and Degree of Starch Gelatinization[a]

Sample	RHT[b] (min)	CWT[c] (g)	STK[d] (N/m^2)	CKT[e] (min)	GSE[f] (%)	GSC[g] (%)
Agglomerated						
Homemade	12c	280.6b	101c	16b	58.8c	54.1c
Commercial	16b	273.4c	178b	16b	61.1b	58.7b
Extruded						
HTST twin-screw[h]	10c	285.0a	185b	6c	92.4a	90.4a
LT single-screw[i]	28a	264.9d	230a	20a	50.0d	47.9d
LSD (0.05)[j]	2.25	4.20	11.32	1.90	4.11	4.20

[a] Means followed by the same letter in each column are not significantly different ($\alpha = 0.05$) by Duncan's multiple range test. Results are means of duplicate analysis.
[b] Rehydration time.
[c] Cooked weight.
[d] Stickiness.
[e] Cooking time.
[f] Gelatinized starch in couscous determined by enzymatic method.
[g] Gelatinized starch in couscous determined by calorimetric method.
[h] High-temperature short-time twin-screw extruder.
[i] Low-temperature single-screw extruder.
[j] Least significant difference, comparison of two means.

TABLE III
Sensory Attributes of Agglomerated and Extruded Couscous[a,b]

Sample	Appearance	Mouthfeel	Flavor	Overall Acceptability
Agglomerated				
Homemade	5.1c	5.0b	5.7c	5.3c
Commercial	6.0b	6.2a	6.4b	6.2b
Extruded				
HTST twin-screw[c]	7.2a	6.6a	7.0a	7.0a
LT single-screw[d]	6.0b	5.4b	5.9c	5.5c
LSD (0.05)[e]	0.60	0.63	0.53	0.59

[a] Means followed by the same letter in each column are not significantly different ($\alpha = 0.05$) by Duncan's multiple range test.
[b] Using a hedonic scale (1–9): 1 = dislike extremely, 9 = like extremely.
[c] High-temperature short-time twin-screw extruder.
[d] Low-temperature single-screw extruder.
[e] Least significant difference, comparison of two means.

Time of rehydration, cooked weight, cooked stickiness, and cooking time are considered to be important cooking quality characteristics (Table II). Couscous produced by the single-screw pasta extruder was dense and compact as indicated by the bulk density (Table I), and consequently had significantly longer rehydration times than those of the twin-screw extruded or the agglomerated couscous. The shortest rehydration times were obtained with the twin-screw (10 min) and the homemade couscous (12 min). The rapid water absorption of these two products may be attributed to the high degree of starch gelatinization in the twin-screw extruded products and to the small particle size of the homemade couscous. Among the four products, the agglomerated homemade couscous showed significantly lower cooked stickiness (Table II). The twin-screw extruded couscous was characterized by its short rehydration time and quick cooking characteristics. The poorest cooking quality was found with the single-screw extruded couscous, due to its excessively dense texture.

During commercial production, couscous is steamed in a conveying belt-type steam cooker to precook the product. Degree of starch gelatinization was used to measure the extent of cooking during this stage. The term starch gelatinization has been used in the literature to denote: 1) loss of starch granule birefringenge during heating; 2) increased susceptibility of starch to enzyme attack; 3) increased dye binding ability of starch; and 4) alteration in starch crystalline organization (Varriano-Martson et al 1980). The amount of gelatinized starch was determined by enzymatic and calorimetric methods. Slightly lower gelatinization values were obtained with the calorimetric than the enzymatic method (Table II). A similar trend was reported by Holm et al (1988). In the enzymatic method, the gelatinized starch is digested by glucoamylase to form glucose, which is colorimetrically titrated after its conversion to *o*-Dianisidine by glucose oxidase and peroxidase. Perhaps some glucose molecules were released from oligosaccharides that were present in the product. A significantly higher amount of gelatinized starch was found in the twin-screw extruded couscous. In extrusion cooking, where low-feed moistures are generally used, starch gelatinization or dextrinization is attributed to mechanical disruption of the organized crystalline structure of the starch granules by high shear action within the extrusion barrel. Approximately 60% of the starch in the agglomerated couscous was gelatinized by the steam treatment. The single-screw extruded couscous showed the lowest amount of gelatinized starch. This product was steamed for the same period of time as the agglomerated couscous. Perhaps a longer time would have been necessary for the steam to penetrate the dense texture that characterizes this product.

In addition to its cooking properties, couscous quality was assessed by its sensory attributes (Table III). Appearance, mouthfeel (firmness and smoothness), flavor, and overall acceptability of the extruded and agglomerated couscous were evaluated by a sensory panel. The twin-screw extruded couscous was rated significantly higher for its appearance and flavor and overall was the best preferred among the four couscous products. The homemade agglomerated and the single-screw extruded couscous were poorly rated for most of the sensory characteristics tested.

CONCLUSIONS

Couscous color was characterized by higher brightness values of the agglomerated couscous, and by higher yellowness value of the twin-screw extruded couscous. The extruded couscous had a uniform shape and size compared to the agglomerated couscous. The twin-screw extruded couscous showed a significantly higher water absorption index, shorter rehydration and cooking times, and better appearance, flavor, and overall acceptability than the agglomerated couscous. The single-screw extruded couscous had poor cooking quality (excessively long rehydration and total cooking times) and was poorly scored for its mouthfeel, flavor, and overall acceptability.

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