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The Improvement of Spaghetti Quality Made from Bread Wheat Flour

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Abstract

Two of the Hard White Winter (HWW) wheats had higher farina yield than mixed Hard Red Winter (HRW) wheat. Optimum steaming time for HRW farina spaghetti was 3min under 86~98° C. Optimum cooking time decreased after steam treatment. Steam treated spaghetti showed much higher strength of dried spaghetti, lower cooking loss, and cooked weight, less stickiness, and total organic matters (TOM) value than in treated spaghetti after cooking. The cooking qualities except stickiness were significantly different between treated and untreated steam. The quality of hard wheat farina spaghetti was more affected than that of durum spaghetti after steam treatment. HWW farina spaghetti improved all the qualities of steam treated and untreated spaghetti than those of HRW farina spaghetti except stickiness. From the observations of scanning electron microscope (SEM), maybe two general principles of steaming can be explained by : i) forming hydrophobic protein film on surface of pasta, ii) higher retrogradation of starch, which cause less swelling of starch.

Key words : spaghetti, cooking quality, farina, steaming

INTRODUCTION

Pasta made from durum wheat has superior color, higher cooked weight, and firmer texture, but higher cooking loss than pasta made from HRW or HRS wheat[1,2]. Kim *et al*[3,4] reported cooking times, cooked weights, and cooking losses were similar between durum and HRW wheat spaghetti. The cutting stress of cooked semolina spaghetti was slightly higher, and its surface was not as sticky as that of farina spaghetti. Also, they added 3% gluten and 1% monoglyceride for improvement of cooking quality with the high temperature drying method. Ideally, cooked spaghetti should be firm, resilient and non-sticky. Russian researchers[5~7] applied steaming to the extruded spaghetti. The starch of macaroni products was increasingly susceptible to amylase hydrolysis[1] after the pasta was treated at 94° C, 98% humidity for 2~5 min, and then dried. The protein was less susceptible to enzyme hydrolysis, because of the firmer surface of denatured protein. The yellow color was not affected by the treatment. The initial tension increased as well as the maximal and tangential tension, the modulus of elastic deformation doubled and the plastic-elastic deformation modulus decreased. Also, steaming firmed the pasta and shortened the time of the spaghetti drying period[6,7]. Heat-moisture treatment of spaghetti made out of hard wheat after extruding would be important in affecting mostly the product surface.

Properties of heat-moisture treated spaghetti might have a firmer surface and more chewiness after cooking because of higher Tm (melting point) and less starch swelling. Also, increased shear resistance and less cooking loss would be expected because of less amylose leached from starch granule.

The exact mechanism for improvement of cooking quality by steaming pasta is not known. Steaming produced a more tightly cross-linked gluten on

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the surface of the spaghetti, which would physically prevent excess swelling of starch during cooking[8-11]. Steaming reduced the swelling properties of potato and wheat starches[12,13] because of the reorientation of the starch polymers within the granules, bringing the intragranular organization. Steam may anneal crystallities in starch granules as would as forming a lysolecithin-amylose complex[16,17].

The objectives of this study were 1) to examine the effects of steaming right after extrusion on spaghetti quality along with physical changes, and 2) to evaluate the potentiality of the use of farina to produce acceptable spaghetti.

MATERIALS AND METHODS

Wheat samples

Fifty-one hard red winter wheat samples were mixed together to give average Kansas hard red winter (HRW) wheat. The HRW samples represented seven varieties of Kansas HRW wheats (Arakn, Newton, Larned, Eagle, Scout 66, Vona and Centurk 78) that were croped during 1982, 1983, and 1984 at eleven locations, some irrigated and some dry land. Two varieties of hard white winter (HWW) wheats were obtained, one from Kansas (KS84 HW196, HWW-K) and the other from Colorado (W81-162, HWW-C). Commercial durum wheat was donated from North Dakota Elevator in 1987.

Milling and spaghetti making

Wheats were tempered and milled using the KSU farina milling scheme[3] at Kansas State University. Spaghetti was extruded as previously reported[3,4]. Immediately after extrusion, the spaghetti was either dried directly or first steamed and then dried. The product was dried at 42°C and 94% R.H. for 1hr, 45°C and 92% R.H. for 5hr, and 57°C and 92% R.H. for 7hr.

Steam treatment

The fresh pasta (10~13cm) was hung on rods, and exposed 1~5 min in the steaming bath. The inside dimensions of the wooden steam chamber were (19.0cm×19.0cm×27.5cm).

Cold-water swelling of spaghetti

Dry spaghetti (10g) was soaked in distilled water (300ml) for 24hours at 25°C, and the samples were photographed.

Cooking quality

Spaghetti cooking quality was determined using the following parameters: cooking time, cooked weight, cooking loss, cutting stress, stickiness[3,4] and total organic matter[14]. Cooking water was artificially hardened as described by Dexter *et al.*[15]

Scanning electron microscopy (SEM)

Specimens were attached to stubs with silver paste and coated under vacuum with approximately 6 nm of carbon and then 10 nm of gold palladium. The surface and the cross section of specimens were examined with an ETEM U-1 Auto scan SEM (Perkin-Elmer Electron Beam Technology, Hayward, CA) operating at 10 kV, and a representative area was photographed on polaroid film, type 55.

RESULTS AND DISCUSSION

Milling

The KSU farina milling method was used to mill one sample of commercial durum wheat, two samples of HWW wheats (HWW-K and HWW-C) and the mixed Kansas HRW wheat. At a constant speck count of 20 specks per ten square inches (stsi), the yield of semolina was 32%, whereas the yields of farina were 14%, 19% and 21% from mixed HRW, HWW-K and HWW-C, respectively (Table 1). The yields of farina from the two HWW varieties were higher than that from HRW due to the lighter color of the seed coat. The protein contents of the durum wheat and semolina were about 1% higher than those of the hard common wheats, and farina

(Table 1).

Optimum steaming time for farina spaghetti

The HRW farina spaghetti was steamed from 1 to 5 min immediately after extrusion. The property of swelling was measured after soaking the dried spaghetti. Cooking qualities were tested for optimum steaming time. One method to test optimum steaming times was to observe the spaghetti during soaking in distilled water 24 hours. Untreated and 1 min steam treated samples of HRW, HWW, and durum spaghetti are seen in Figs. 1-a, -b. Durum spaghetti produced the clearest soaking water, followed by HWW (K), and then HRW farina. Increasing the steaming time for HRW farina from 1 to 3 min dramatically decreased the turbidity of the soaking water (Fig. 1-c). The strengthening of the spaghetti strands by steaming was also evidenced by the retention of the shape of the individual strands after soaking (Fig. 2). To obtain the optimum steaming time of HRW-farina spaghetti, we also measured cooking quality (Table 2). The optimum cooking time decreased as the steaming time increased. When we measured the optimum cooking time, the starch core of spaghetti could not be observed as readily as in untreated spaghetti, since the starch core had already disappeared after steaming. It was not easy to measure the optimum cooking time by squeezing cooked spaghetti between two plexiglass plates from steam treated samples; thus, the optimum cooking time by chewing after cooking, which gives a larger error than disappearances of unsteamed strands in the core. Cooked weight and cooking loss decreased after steaming (Table 2). These changes would be expected due to the effects of heat-moisture treatment on starch. Sair[16,17] observed that heating of starches at restricted moisture levels (heat-moisture treatment) dramatically changed the properties of starches, including gelatinization temperature ranges, swelling behavior, and

Table 1. Milling data of HRW, HWW, and durum

Sample	Wheat protein (%)	Farina or Semolina Protein (%)	Farina or Semolina Yield (%)	Speck count (stsi*)	Pigment (ppm)	Yield of semolina or farina wi-th<20stsi (%)
HRW	12.1	10.9	42.4	77	1.38	14
HWW-K**	11.8	10.7	43.7	64	1.52	19
HWW-C***	11.9	11.2	42.6	60	1.64	21
Durum	13.2	12.4	48.4	48	3.28	32

*Specks per ten square inch
**KS84HW196 (Hard White Winter wheat croped from Kansas)
***W81-162 (Hard White Winter wheat croped from Colorado)

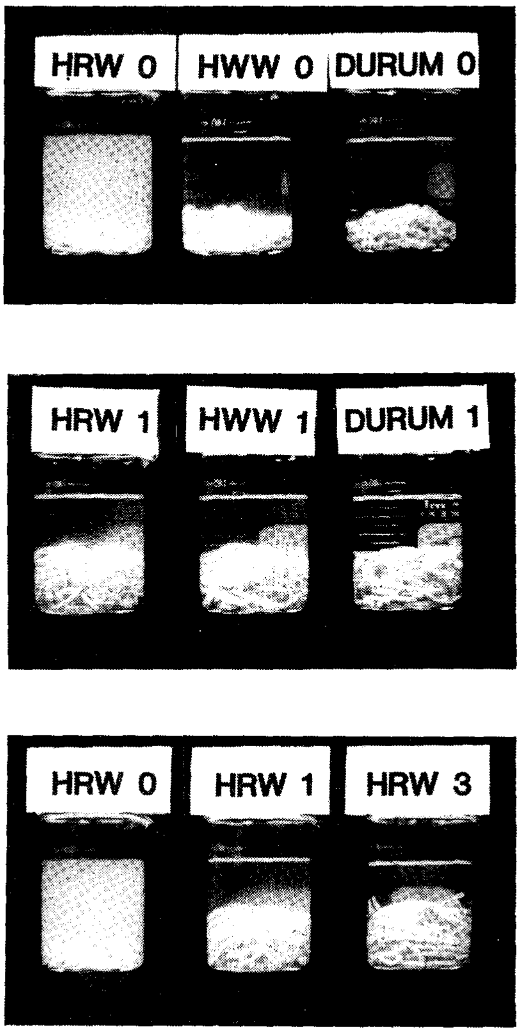

Fig. 1. Steam untreated HRW, HWW (K), and durum spaghetti (a), 1 min steam treated HRW, HWW (K), and durum spaghetti (b), and 0, 1 and 3 min steam treated HRW spaghetti (c) sample.

paste translucency. Kulp and Lorenz[12], and Lorenz and Kulp[13] found that gelatinization temperature, water-binding capacity, and enzyme susceptibility increased after moist-heat treatment of potato and wheat starches. They also reported that viscograph consistency and swelling power decreased with increasing moisture from 18 to 27% during heat treatment at 100°C for 16hr. The potato starch type B pattern, characteristic for tuber starches, changes to a typical cereal A pattern with a concomitant shift of the starch properties in the same direction from X-ray diffraction patterns. Wheat starch retains the A pattern, and its characteristics are less affected by the treatment[12]. According to Zobel[18], heat-moisture treated starch give higher Tm, less swelling, more shear resistance and less set-back of starch paste. Seguchi[8] suggested that heat treatment gives wheat starch a hydrophobic surface, because of the denatured protein on its surface.

The cutting stress increased after steaming up to 4min, whereas stickiness decreased until 3min but the increased after 4 and 5min steam treatment

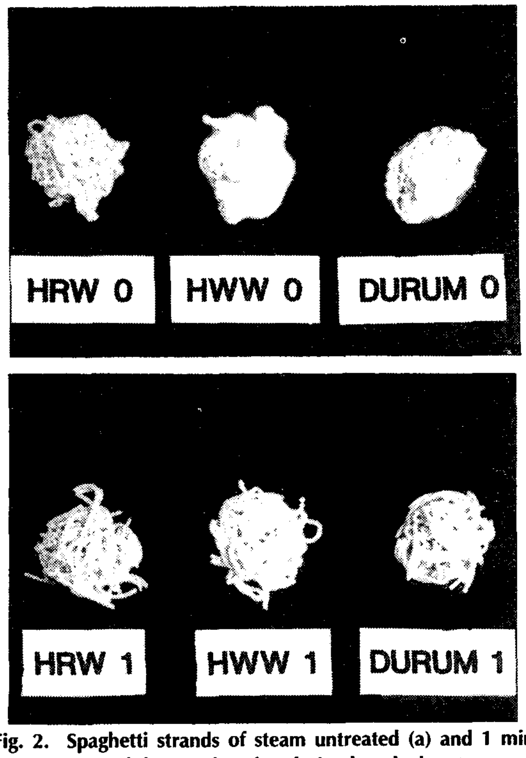

Fig. 2. Spaghetti strands of steam untreated (a) and 1 min treated (b) samples after drained cooked-water.

(Table 2). Thus, longer steaming caused the decrease in free water of spaghetti when squeezed the surface of cooked spaghetti which may cause increased the stickiness after 4 or 5min steaming (Table 2). From the above results, we concluded 3min steaming was optimum for HRW farina.

Quality of dried spaghetti

HRW spaghetti was steamed 3min to obtain optimum cooking quality. Upon drying of the steamed hard wheat spaghetti, the thickness of the strands decreased from 1.7% to 2.8%, whereas durum spaghetti decreased 0.6% after steam treatment (Fig. 3).

The breaking stresses of treated and untreated spaghetti from each wheat variety are shown in Fig. 4. Hard wheat spaghetti of breaking stress increased dramatically from 57 to 160%, whereas that of durum spaghetti increased only 26%. The stability of durum wheat gluten was higher than that of hard wheat gluten. The standard deviation of breaking stress values of each sample was high, probably due to the size of die holes which are not uniform. Therefore, the small laboratory batch system could not get uniform thickness of spaghetti, especially af-

Table 2. Cooking characteristics of HRW farina spaghetti after various steam treatment times

Heat treatment (min)	Optimum cooking time (min)	Cooked weight (g)	Cooking loss (%)	Cutting stress (kN/m²)	Stickiness (N/m²)
0	12.80 ±0.30	26.97 ±0.07	7.16 ±0.35	27.40 ±1.47	1537.00 ±92.00
1	10.92 ±0.59	25.26 ±0.18	6.50 ±0.45	34.50 ±1.47	1542.00 ±61.00
2	10.75 ±0.61	24.65 ±1.06	6.13 ±0.54	37.20 ±2.81	1478.00 ±54.50
3	10.50 ±0.42	23.76 ±0.12	6.08 ±0.32	39.60 ±1.75	1456.00 ±37.00
4	9.58 ±0.44	23.81 ±1.11	6.02 ±0.05	40.65 ±2.35	1551.00 ±55.00
5	9.25 ±0.25	23.07 ±0.14	5.78 ±0.35	39.40 ±1.90	1580.00 ±72.00

ter steam treatment.

Cooking quality of spaghetti

Optimum cooking time of untreated durum showed the shortest (11.5min), but treated HWW (C) spaghetti produced the shortest optimum cooking time after steam treatment (Fig. 5). Cooked weight and cooking loss also decreased after steam treatment (Figs. 6 and 7). The decreasing rate of cooked weight (7.0%) and cooking loss (2.1%) of durum spaghetti was the lowest. Cutting stress of hard wheat spaghetti increased from 33.6% to 64. 3%, whereas durum spaghetti increased 12.0% (Fig. 8). To know the surface condition of steam untreated and treated spaghetti, we measured the stickiness by using instron and total organic matter (TOM) by chemical titration. Stickiness values of farina spaghetti of HRW and HWW (C) decreased about 5.3% ~ 11.0%, whereas durum spaghetti was decreased 9.4%, but HWW (K) increased about 13% (Fig.9). The increased stickiness of HWW (K) showed that the apparent stickiness of a given sample is strongly influenced by the amount of unabsorbed water associated with cooked spaghetti following drainage[15]. Also, it suggested that a high concentration of amylose on the surface of cooked spaghetti may

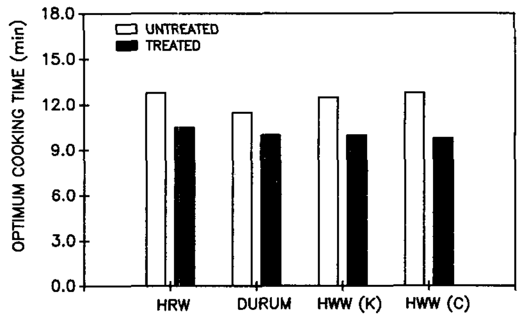

Fig. 5. Optimum cooking time of each dried spaghetti between steam untreated and treated samples.

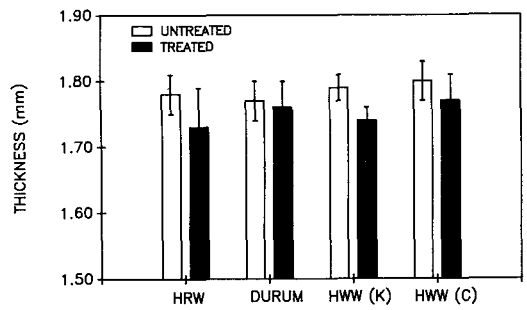

Fig. 3. Thickness of each dried spaghetti between steam untreated and treated samples.

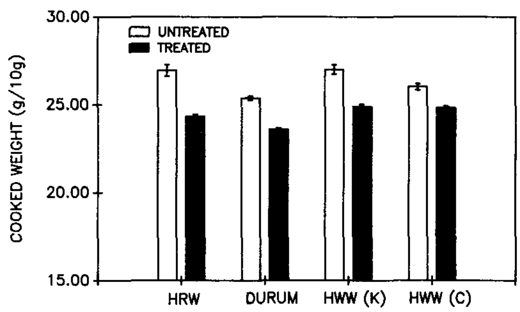

Fig. 6. Cooked weight of each dried spaghetti between steam untreated and treated samples.

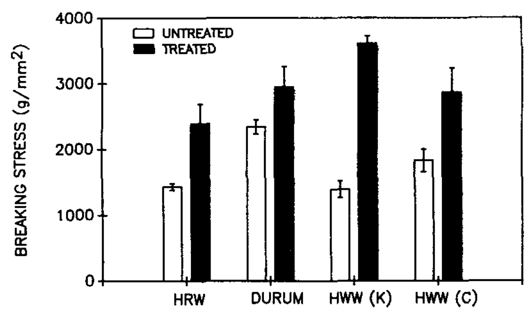

Fig. 4. Breaking stress of each dried spaghetti between steam untreated and treated samples.

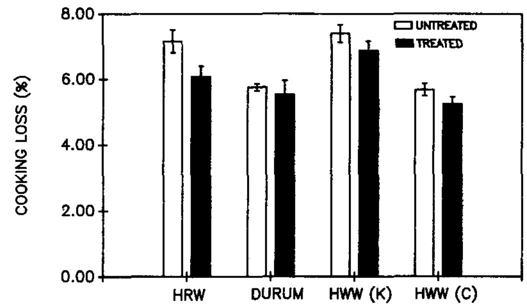

Fig. 7. Cooking loss of each dried spaghetti between steam untreated and treated samples.

contribute to stickiness. Thus, the treatment of steaming may reduce the concentration of amylose on the surface. TOM value of all the treated spaghetti decreased (Fig. 10), but the condition of the spaghetti surface did not correlate between stickiness and TOM value. The surface stickiness may be influenced by not only change of starch but also by protein. Stickiness did not improve significantly, but remaining cooking quality improved a lot by steaming.

Scanning electron microscopy (SEM)

A noticeable effect of the steaming step (3min) on the shape of the starch granules can be seen on those steamed at 86~94°C. SEM of the steam untreated (Figs. 11 (HRW), 13 (durum)) and treated spaghetti (Figs. 12 (HRW), 14 (durum)) were shown. From the each Figure, -a was taken from the whole cross section, -b was taken from edge area of the cross section, -c was taken from a little bit inside of the cross section, and -d was taken from surface of the spaghetti. When the spaghetti was broken, the cross section part of steam treated HRW farina spaghetti (Fig. 12-a) showed more distinguishable edge crack and higher denaturation than that of du-

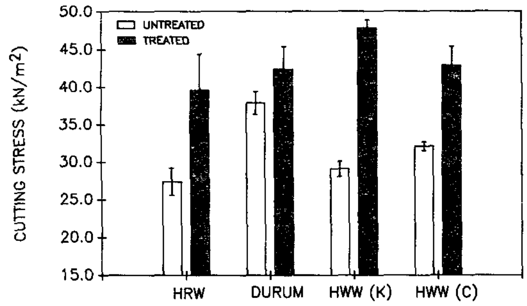

Fig. 8. Cutting stress of each dried spaghetti between steam untreated and treated samples.

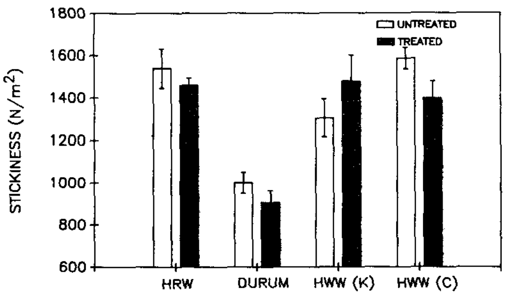

Fig. 9. Stickiness of each dried spaghetti between steam untreated and treated samples.

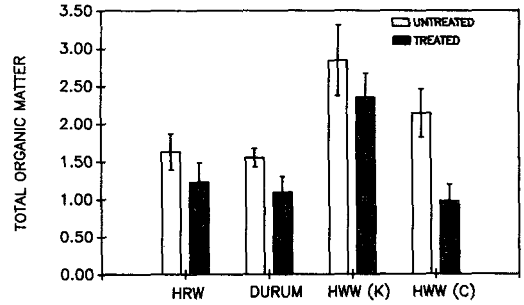

Fig. 10. Total organic matter (TOM) of each dried spaghetti between steam untreated and treated samples.

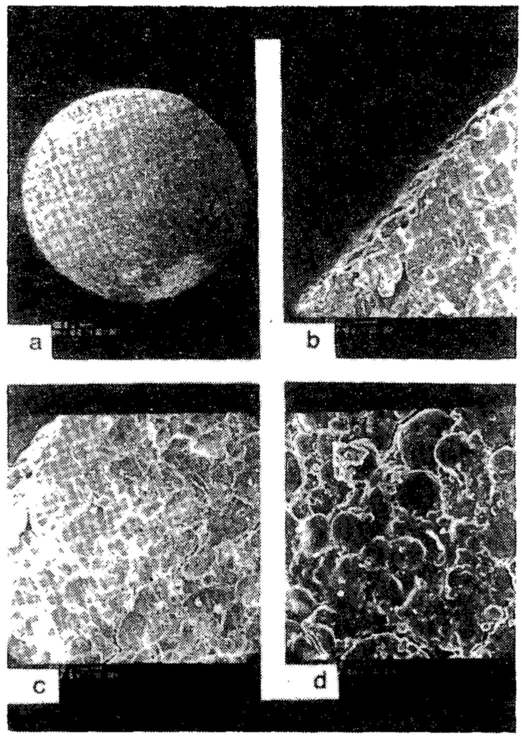

Fig. 11. Scanning electron microscopy of steam untreated HRW dried spaghetti.
(a) Whole cross section
(b) Edge of cross section
(c) Inside of the cross section
(d) Surface

rum (Fig. 14-a), which means farina gluten was stronger than durum gluten. Steam treated samples were showen more smoothly organized between protein and starch. Steam treatment of HRW spaghetti showed more denatured protein than durum spaghetti; thus, the overall quality of hard wheat spaghetti was improved more than durum spaghetti. The strength of gluten may control the different action between protein and starch granules. Comparing Fig. 11-b, -c and Fig. 13-b,-c, HRW spaghetti had higher cracks than durum spaghetti. From the surface of HRW spaghetti (Fig.11-d) and durum spaghetti (Fig. 13-d), HRW spaghetti surface had more rough and big cracks than did durum spaghetti. The surface of HRW spaghetti (Fig. 12-d) showed that each starch granule can be easily distinguished, but not in durum spaghetti (Fig. 14-d) after cooking. Numerous starch granules of varying size were visible on the outer surface of dry spaghetti (Figs.11-a, 12-a, 13-a, 14-a). The entire surface of the dry spaghetti appears to be coated with a smooth protein film. Numerous small holes and cracks were also shown. In contrast, a cross section of dry spaghetti (Figs. 11-b,c, 12-b,c, 13-b,c, and 14-b,c) exhibited a structure where few starch granules were evident, and these were completely coated with an amorphous protein matrix. Dexter *et al*[18, 19] proposed that strong gluten in pasta may give a more rigid and less flexible structure than weak gluten. They also suggested that denaturation of a thin protein film during pasta drying might be associated with improved surface stability during cooking[19,21].

By comparison with the traditional process used for Asia rice noodle manufacture, the idea had been proposed of further gelatinizing the starch after extrusion in order to improve the resistance of spaghetti to disintegration in boiling water, as a result

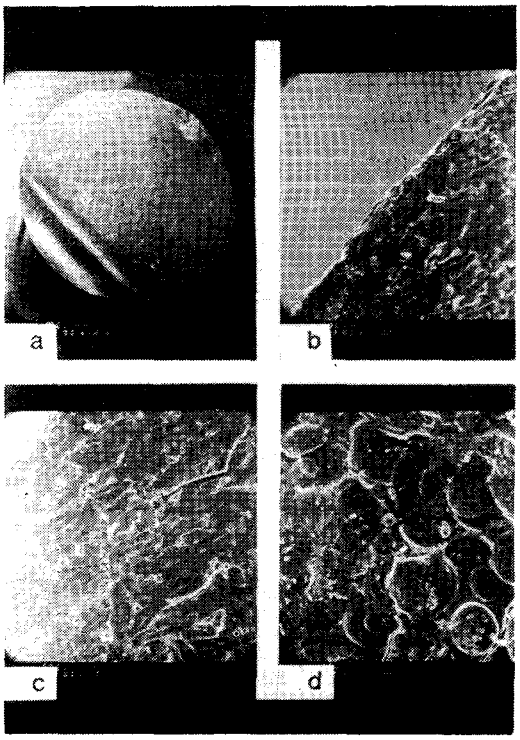

Fig. 12. Scanning electron microscopy of steam treated HRW dried spaghetti.
(a) Whole cross section
(b) Edge of cross section
(c) Inside of the cross section
(d) Surface

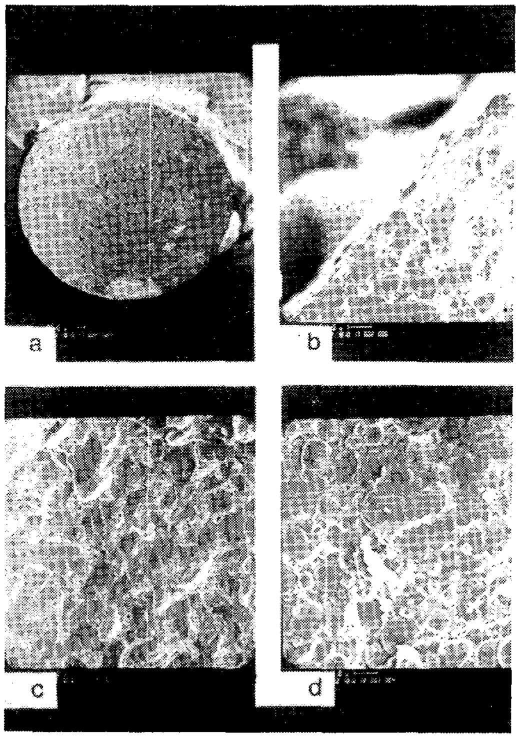

Fig. 13. Scanning electron microscopy of steam untreated *durum* dried spaghetti.
(a) Whole cross section
(b) Edge of cross section
(c) Inside of the cross section
(d) Surface

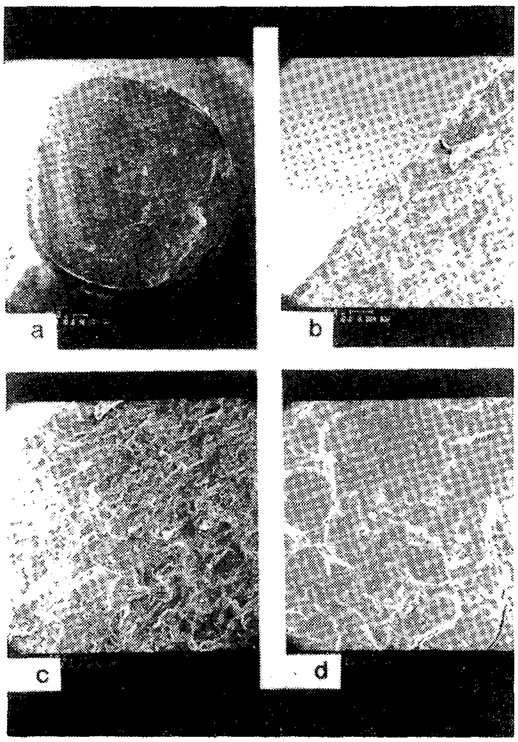

Fig. 14. Scanning electron microscopy of steam treated durum dried spaghetti.
(a) Whole cross section
(b) Edge of cross section
(c) Inside of the cross section
(d) Surface

of reorganization of the retrograded starch network. There is a possibility that during steaming the protein film on the surface of spaghetti[19] is strengthened, leading to increased resistance to strand disintegration.

All of these findings should be of great interest to countries where durum wheat is not grown.

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제빵용 밀가루를 이용한 스파게티 제조 적성의 향상

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요 약

4종의 제빵용 밀가루를 사용하여 스파게티를 통상의 제조법에 따른 경우는 제품의 질적 저하를 막을 수가 없다. 본 연구에서는 건조직전, 즉 압출 직후에 스팀증기 처리를 함으로써 스파게티의 질적 향상을 도모 하였다. 스팀처리의 시간은 3분이 가장 적절 하였으며, 이를 제조후 건조된 상태에서의 경도 (breaking stress), 삶은 이후의 질적 관찰에서 적정 조리 시간(optimum cooking time), 조리이후의 손실(cooking loss), 견고성(cutting stress), 점착성(stickiness), 전 유기물 정량 (total organic matter) 등에서 거의 대부분의 질적 향상이 뚜렷하였다. 그러나 건조후 면의 굵기 (thickness), 조리후의 무게(cooked weight)는 스팀 처리 이후에 감소함을 알 수 있었다. 또 HWW(Hard White Winter) 밀과 듀럼(Durum) 밀을 주사현미경(scanning electro microscope)으로 관찰한 결과 전분이 스파게티 표면에서 단백질과 더욱 단단한 결합을 이루고 있음을 보여 주었으며 이는 아마도 전분이 스파게티 표면에 스팀처리에 의한 소수성 막을 형성하며, 높은 노화 작용에 의하여 조리후 더 낮은 팽윤을 하는것으로 보여진다.