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Comparison of Physicochemical Properties of Korean and Australian Wheat Flours Used to Make Korean Salted Noodles

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Abstract The effect of using Korean wheat flour versus Australian wheat flour on noodle quality as a result of differing physical and chemical properties of the flours was investigated. The results provided appropriate technical information for selection of wheat varieties to produce high quality Korean salted noodles. Noodle quality was quantified based on measurement of the appearance and texture of noodles. When consumer preference tests were conducted, a firmer and more elastic texture was preferred for Korean white salted noodles, however, when appearance was included in the consumer tests, noodles made with Australian wheat were favored over Korean wheats. Korean flour was found to produce firmer and more elastic noodles, whereas Australian flour produced brighter, creamier colored noodles. In flour quality tests, Korean flours were found to have a higher setback viscosity and lower swelling power than Australian flour. Additionally, Korean flours had higher water absorption values. Protein content of flour was an important parameter affecting the firmness of Korean noodles, whereas setback viscosity and swelling power were the major determinants of elasticity. Overall, the important parameters for determination of the quality of Korean salted noodles were high setback viscosity, low swelling power, and high protein content.

Keywords: wheat flour quality, Korean salted noodle, physicochemical property, textural analysis, consumer preference

Introduction

White salted noodles are the most popular noodles in Korea. In recent years, a large amount of Australian wheat has been exported to Korea. Due to the increased proportion of Australian wheat in white salted noodles, it is important to examine its impact on noodle quality. Several studies evaluating the physical and chemical properties of wheat flour have been conducted on Japanese white salted noodles *udong* (1-5), Asian (6, 7) and oriental noodles (8, 9).

Starch and protein in wheat flour are important for determining the quality of white salted noodles (10). Previous studies found that protein content was significantly correlated with the eating quality of Japanese white salted noodles, and that the optimum proportion of protein in flour was 9-10% (2, 11, 12). Further, many Australian wheat varieties are suitable for Japanese white salted noodles (2).

However, relatively little is known about eating quality preference and the quality of flour required to attain desired eating preferences of Korean white salted noodles (*guksu*), therefore this study was designed to investigate Korean preferences for fresh white salted noodles and subsequently establish quality guidelines of wheat flours for fresh Korean white salted noodles.

Materials and Methods

Materials Korean wheat samples (*Al-chan, Geu-roo, and Keum-kang*) were obtained from the Dae-Han Flour Milling Company, South Korea. Six Australian wheat varieties (*Cadoux*, *Arrino*, *Callingiri*, *Eradu*, *Gutha*, and *Nyabing*) from 2 regions (Wongan Hills and Mingenew) were supplied by Agriculture Western Australia.

Properties of flour samples Protein, ash, and moisture content of flour were determined using AACC methods 30-25, 08-01, and 44-15A, respectively (13). Total starch and amylose content was determined using a Megazyme assay kit (Megazyme International Ireland, Wicklow, Ireland). Farinograph properties, including dough development time, stability, and breakdown were determined using AACC method 54-21 (13). The extensibility of flour was measured using AACC method 54-10 (13). Pasting viscosity properties were measured using a Rapid Visco Analyser (Newport Scientific, Sydney, Australia) (15). Flour swelling power was measured using a previously described method (5, 14). The color of flour and raw noodle sheet was determined using a Minolta Chroma Meter (Model CR310; L*, a*, and b* Color System, Tokyo, Japan) with an 11-mm aperture. The CIE-Lab L*, a*, and b* values denote brightness, redness-greenness, and yellowness-blueness, respectively.

Noodle making White salted noodles were prepared using the method described by Konik *et al.* (2). Wheat flour (100 g, 13.5% m.b.) was mixed with salt (3%), and distilled water (30 mL) using a Hobart mixer. The dough was then placed in a plastic bag for 2 hr at ambient temperature, at which time it was passed through rollers with a gap of 4.5 mm. The dough sheet was folded into thirds and passed through rollers twice. Sheeted dough was placed in a plastic bag for 2 hr, then passed through rollers 5 times, each time with a gradual reduction of the roller gap (4.3 mm → 3.7 mm → 3.3 mm → 2.7 mm → 2.0

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mm). The sheet was then cut into noodle strands (2.0 mm thick and 1.5 mm wide) which were cooked 2 hr later.

Textural analysis of cooked noodles The optimum cooking time was determined using visual observations of the disappearance of the white core of the noodles while cooking (16). Cutting and compression force of cooked noodles were measured using a Texture Analyser (TA-XT2; Stable Micro Systems Ltd., Surrey, UK). Noodles (50 g) were cooked in 5 L boiling water for the optimum cooking time, and then rinsed with cold water for 1 min. The cooked noodles were kept in 600 mL cold water for 2 min before analysis using the Texture Analyser.
Firmness and elasticity were determined using methods previously described (12, 16).

Noodle preparation and quality evaluation The noodles were cooked in boiling water 2 hr after they were made. After being drained for 30 sec, they were rinsed 3 times in cold water. The rinsed noodles were served in a very thin seasoned soup to allow sensory evaluation. Noodles quality was assessed by female Korean consumers currently residing in Sydney, Australia. The group was comprised of 30 women between the ages of 30 and 50. Parameters tested included general appearance, color, firmness, elasticity, taste, and overall acceptance. Cooked noodles were scored using the following scale: 9, like extremely; 5, neither like nor dislike; and 1, dislike extremely (17).

Statistical analyses Statistical analyses were conducted using the SAS software system (version 9.1, SAS Institute, Cary, NC, USA). Data were expressed as means plus or minus standard deviation (SD). The 2 groups were compared using the student's *t*-test and. Differences were considered statistically significant if $p<0.05$. Pearson correlation coefficients were calculated to evaluate associations between physicochemical properties and cooked noodle quality.

Results and Discussion

Physicochemical properties of flour samples The average physicochemical properties of Korean and Australian flours are shown in Table 1. Korean wheat varieties had much higher protein content (12.2%) than the selected Australian wheat varieties (4). The total starch content of the Korean flour was between 76.3 and 80.4%, whereas the Australian flour was slightly higher, between 78.3 and 85.2%. The amylose content of flour samples was between 26.7 and 28.5% in Korean samples and 25.2 and 29.2% for Australian varieties. Slightly higher L* values were observed in Korean flour, whereas Australian flour had a significantly higher a* and b* values. The yellow pigment of Australian varieties varied more than Korean varieties.

Korean varieties contained a significantly lower RVA peak viscosity ($p<0.01$) and higher setback viscosity ($p<0.01$) than Australian varieties (Table 2). In particular setback viscosity of Korean wheat flour had a wider range than that of Australian wheat. The lowest RVA pasting viscosity property was observed in the *Keum-kang* variety of Korean wheat, which had the highest (15.1%) protein content.

The composition of starch and protein in wheat is important when determining end-product quality of white salted noodles (10). Quality characteristics that contribute to the production of improved white salted noodles include high starch pasting peak viscosity, low protein content, low amylose content, and high protein quality (10).

Korean wheat had a significantly lower swelling power than Australian wheat ($p<0.01$). Additionally, Australian wheat had a slightly greater range of water adsorption than Korean wheat.

Dough development time was similar between both groups of wheat samples (Table 3). Extensograph results indicated that Australian varieties were not as strong, but had greater extensibility than Korean wheat samples.

In general Korean and Australian wheat contained different starch characteristics and protein quality.

Quality of white salted noodles and correlation to physicochemical properties Noodles made with Korean wheat flours required a significantly longer cooking time ($p<0.01$) than noodles made from Australian wheat flour (Table 4).

All Korean wheat noodles were firmer and more elastic

Table 1. Physicochemical properties of wheat flour samples[1)]

Parameters	Korean varieties			Australian varieties		
	Mean	Range	SD[2)]	Mean	Range	SD
Protein (%)	12.2	10.1-15.1	2.61	9.7	8.7-11.1	0.75
Ash (%)	0.4	0.36-0.43	0.04	0.4	0.33-0.43	0.03
Moisture (%)	11.2	11.0-11.5	0.26	11.7	11.1-12.1	0.3
Total starch (%)	79.1	76.3-80.4	2.4	80.8	78.3-85.2	2.04
Amylose (%)	27.3	26.7-28.5	1.3	26.9	25.2-29.2	1.36
Minolta L*	93.0	92.3-93.4	0.57	92.5	91.8-93.0	0.42
Minolta a*	-0.6	-0.4--0.7	0.15	-0.5	-0.3--1.0	0.23
Minolta b*	6.8	6.4-7.2	0.4	8.3	6.5-12.1	1.57

[1)]No significant differences between groups were observed in any parameters.
[2)]Standard deviation.

Table 2. Pasting properties and swelling power of wheat flour samples

Parameters	Korean varieties			Australian varieties		
	Mean	Range	SD[1)]	Mean	Range	SD
Peak time (min)[2)]	5.2	5.11-5.22	0.13	5.0	4.70-5.28	0.10
Peak viscosity[2)]**	297	276-310	16.36	317	303-335	9.98
Breakdown viscosity[2)]	88.7	82.0-96.0	7.0	118.5	88.5-145.0	18.9
Setback viscosity[2)]**	166	154-176	3.01	134	128-150	5.90
Final viscosity[2)]	373.8	362.0-397.5	20.5	333.3	311.5-388.5	22.4
Swelling power**	8.5	7.82-8.85	0.59	10.5	10.15-11.16	0.36

[1)]Standard deviation.
[2)]Measured by Rapid Visco Analyser with 2% NaCl solution. **p<0.01.

Table 3. Farinograph and extensograph properties of wheat flour samples[1)]

Parameters	Korean varieties			Australian varieties		
	Mean	Range	SD[4)]	Mean	Range	SD
Water absorption (%)[2)]	59.8	55.4-63.8	4.22	53.2	50.0-60.1	3.02
Dough D.T. (min)[2)]	3.2	1.5-6.0	2.47	3.8	2.8-6.2	1.02
Maximum resistance (EU)[3)]	425	375-480	52.68	350	240-430	78.17
Extensibility (cm)[3)]	17.8	14.3-20.3	3.14	21.8	20.1-24.0	1.37

[1)]No significant differences between groups were observed in any parameters.
[2)]Water absorption and dough development time measured by farinograph.
[3)]Measured by extensograph.
[4)]Standard deviation.

Table 4. Textural quality of cooked noodles and color of raw noodle sheet

Parameters	Korean varieties			Australian varieties		
	Mean	Range	SD[2)]	Mean	Range	SD
Optimum C.T. (min)[1)]**	13.0	0.07-0.14	1.00	10.4	9-11.5	0.70
Firmness (N)*	1.09	1.00-1.17	0.08	0.99	0.91-1.11	0.06
Thickness (cm)**	2.87	2.91-3.05	0.20	2.15	1.86-2.35	0.16
Elasticity (N)	0.31	0.28-0.36	0.04	0.25	0.11-0.29	0.05
Minolta L**	83.4	81.2-6.8	2.99	86.6	84.8-8.2	1.06
Minolta a*	1. 9	0.9-2.7	0.89	1.4	0.7-2.1	0.39
Minolta b*	13.4	11.8-4.6	1.43	19.0	13.1-6.3	3.53

[1)]Optimum cooking time.
[2)]Standard deviation. **p<0.01, *p<0.05.

than Australian wheat noodles, however there was a large overlap in the ranges of firmness for the two sets of samples.

Similar Minolta L* and a* values were obtained for both Korean and Australian dough sheets, however, the Australian wheat dough sheet had a higher Minolta b* value than the Korean wheat dough sheet.

Cooking time appeared to be correlated with protein content (r = 0.74, p<0.01) (Table 5). Thickness of cooked noodles was affected by flour swelling property as well as protein content (r = -0.89 and 0.67, p<0.01, respectively). A significant negative correlation was found between the thickness of cooked noodles and both peak viscosity and breakdown viscosity (r = -0.79 and -0.84, p<0.01). Farinograph water absorption appeared to have a great impact on cooked noodle thickness (r = 0.83, p<0.01).

When flour physicochemical properties and noodle quality were considered, swelling power (r = -0.78, p<0.01), RVA peak viscosity (r = -0.68, p<0.01), RVA setback viscosity (r = 0.69, p<0.01) and protein content (r = -0.74, p<0.01) were significantly correlated with optimum cooking time.

No significant correlation was observed between optimum cooking time and total starch content, amylose content, or farinograph, or extensograph results, indicating that protein content and starch properties of flour, including pasting viscosity and swelling power, were the primary determinants of optimum cooking time. Therefore, optimum cooking time of white salted noodles can be predicted using protein content as well as physicochemical properties of starch.

Of the physicochemical properties tested, RVA setback

Table 5. Correlation coefficients between physicochemical properties and cooked noodle quality

Parameters	Firmness (N)	Thickness (cm)	Elasticity (N)	Optimum cooking time (min)	Swelling power
Protein content (%)	0.61*	0.67**	0.40	0.74**	-0.82**
Ash content (%)	0.13	0.28	0.33	0.25	-0.40
Total starch (%)	0.02	-0.18	0.17	-0.40	0.35
Amylose (%)	-0.05	-0.05	0.09	0.32	-0.21
Peak viscosity (RVU)[1)]	-0.60*	-0.79**	-0.46	-0.68**	0.80**
Breakdown viscosity (RVU)[1)]	-0.66**	-0.84**	-0.55*	-0.67**	0.87**
Setback viscosity (RVU)[1)]	0.53*	0.81**	0.67**	0.69**	-0.87**
Final viscosity (RVU)[1)]	0.22	0.33	0.42	0.21	-0.39
Water absorption (%)[2)]	0.47	0.83**	0.47	0.46	-0.76**
Dough development time (min)[2)]	0.24	0.00	0.16	-0.01	-0.04
Maximum resistance (EU)[3)]	0.501	0.20	0.46	0.41	-0.32
Extensibility (cm)[3)]	-0.26	-0.52*	-0.26	-0.61*	0.52*
Swelling power	-0.55*	-0.89**	-0.44	-0.78**	1.00

[1)]Measured by Rapid Visco Analyser with 2% NaCl solution.
[2)]Measured by farinograph.
[3)]Measured by extensograph. ** $p<0.01$, * $p<0.05$.

Table 6. Correlation coefficients between flour quality and appearance of raw noodle sheet

Color	Protein content (%)	Ash content (%)	RVA[1)] Peak viscosity (RVU)	RVA[1)] Setback viscosity (RVU)	Farinograph Water absorption (%)	Farinograph Development time (min)	Extensograph Maximum resistance (EU)	Swelling power
Minolta L*	-0.90**	-0.29	0.67**	-0.69**	-0.55*	-0.33	-0.45	0.79**
Minolta a*	0.82**	0.5	-0.53*	0.5	0.47	0.46	0.29	-0.62*
Minolta b*	-0.11	-0.52*	0.56*	-0.43	-0.35	0.41	0.05	0.44
Minolta L*-b*	-0.31	0.34	-0.19	0.07	0.06	-0.52*	-0.26	-0.03

[1)]Measured by Rapid Visco Analyser with 2% NaCl solution.
** $p<0.01$, * $p<0.05$.

viscosity (measured in 2% NaCl solution) had the highest correlation with textural quality (r = 0.67, $p<0.01$). This result is similar to those of Yun *et al.* (18), which found setback viscosity to be the most important starch pasting viscosity parameter for prediction of white salted noodle quality (18).

Protein content and swelling power (r = 0.61 and -0.55, $p<0.05$, respectively) were also highly correlated with firmness. Protein content appeared to be more important than swelling power after setback viscosity when determining firmness. No significant correlation was observed between firmness and any other property, including ash content, RVA final viscosity, farinograph and extensograph results.

Swelling power showed a strong negative correlation with protein content (r = -0.82, $p<0.01$) positive correlation with RVA peak viscosity (r = 0.80, $p<0.01$). Water absorption was positively correlated with thickness (r = 0.76, $p<0.01$) and negatively correlated with swelling power (r = -0.76, $p<0.01$).

Firmness and elasticity were also compared with RVA pasting viscosity, as measured in 1 mM $AgNO_3$ solution. Addition of 2% NaCl resulted in pasting viscosity with a greater correlation to firmness and elasticity than viscosity in 1 mM $AgNO_3$ (data not shown). Previous reports have shown that the correlation between salt-added pasting properties and noodle quality parameters were generally improved compared to noodles without added salt (18). Further, starch quality has been found to be the major determinant of salted noodle quality.

Based on these results, it is clear that both protein and starch play an important role in the texture of white salted noodles.

Elasticity was measured by estimating compression energy over thickness of cooked noodles. Maximum resistance, as determined using an extensograph, was positively correlated with elasticity. Unlike protein content, compression test results and farinograph and extensograph results were not well correlated; therefore further study is required to confirm this correlation. Most compression measurements appeared to be positively correlated with setback viscosity, whereas swelling power indicated a negative correlation.

Overall, these results indicate that setback viscosity is the most important RVA viscosity parameter for predicting eating quality of cooked Korean white salted noodles.

Appearance of dough sheet and noodle quality Appearance of noodles is the first critical assessment of noodle quality made by a consumer (19), therefore the physicochemical properties of flour were compared with the Minolta L*, a*, and b* values of raw noodle dough sheets (Table 6). Brightness and absence of an undesirable discoloration are essential to consumer acceptance of white salted noodles (20), and the color of a noodle sheet was affected by wheat cultivars and protein content (21).

Peak viscosity and swelling power (r = 0.67 and 0.80, $p<0.01$, respectively) were positively correlated with raw dough sheet brightness (L*).

Protein content was significantly negatively correlated with the brightness (L*) of the dough sheet (r = 0.90, $p<0.01$), similar to the findings of Oh *et al.* (19). It has also been reported that protein content should be between 12-13% because of its negative effect on noodle color (21-24).

Minolta b* value of dough sheet was most affected by peak viscosity, followed by ash content. As a result, color of raw noodle sheets was significantly affected by flour composition and starch properties.

No significant correlation was found between color stability (L*-b*) of dough sheet and flour properties measured in this study. Further study is required to confirm correlation between the color of the dough sheet and noodle quality.

Korean preference for salted noodles The preference test was comprised of three parts, including appearance (color), texture, and overall preference (Fig. 1).

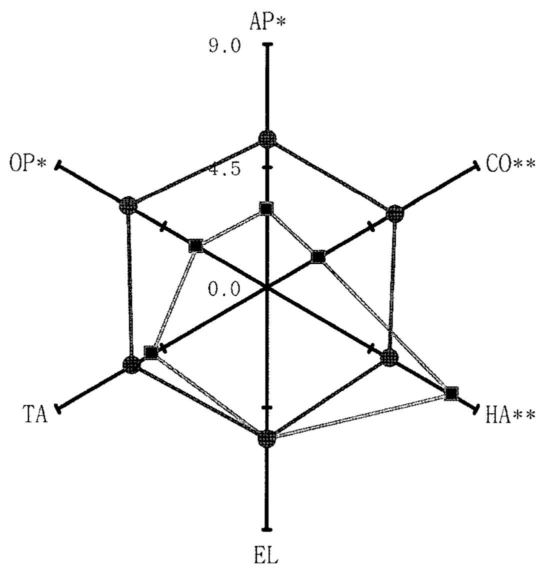

Fig. 1. Results of the preference test of cooked noodles. AP, Appearance; CO, color; HA, hardness; EL, elasticity; TA, taste; OP, overall preference. **, *Significant difference at $p<0.01$ and $p<0.05$, respectively, by *t*-test. –■–, Korean wheat flours; –●–, Australian wheat flours.

Overall data indicated that appearance ($p<0.05$), color ($p<0.01$), elasticity, taste, and overall preference ($p<0.05$) was higher when Australian varieties of flour were used, whereas Korean varieties were preferred when texture, including hardness, was considered ($p<0.01$). Korean wheat produced noodles with a firmer texture than Australian wheat (Table 6).

Appearance of cooked noodles was positively correlated with color of cooked noodles (r = 0.9, $p<0.01$) and the b* value of flour was significantly correlated with the appearance of cooked noodles (r = 0.8, $p<0.05$) and cooked noodle color value (r = 0.9, $p<0.01$, results not shown), similar to results reported by Yun *et al.* (18).

Australian wheat produced good color and was the most preferred variety based on overall acceptance in this study.

In this study, overall preference was for noodles made from Australian varieties of wheat, indicating that consumer preference was based on appearance rather than texture. Further work is necessary to confirm these results.

References

1. Konik CM, Miskelly DM, Gras PW. Contribution of starch and non-starch parameters to the eating quality of Japanese white salted noodles. J. Sci. Food Agr. 58: 403-406 (1992)
2. Konik KM, Miskelly DM, Gras PW. Starch swelling power, grain hardness, and protein: Relationship to sensory properties of Japanese noodles. Starch-Stärke 45: 139-144 (1993)
3. Oda M, Yasuda Y, Okazaki S, Yamauchi Y, Yokoyama Y. A method of flour quality assessment for Japanese noodles. Cereal Chem. 57: 253-254 (1980)
4. Toyokawa H, Rubenthaler GL, Powers JR, Schanus EG. Japanese noodle qualities. I. Flour components. Cereal Chem. 66: 382-386 (1989)
5. Crosbie SB, Lambe WJ, Thutsui H, Gilmour RF. Further evaluation of the flour swelling volume test for identifying wheats potentially suitable for Japanese noodles. J. Cereal Sci. 15: 271-280 (1992)
6. Seib PA, Liang X, Guan F, Liang YT, Yang HC. Comparison of Asian noodles from some hard white and hard red wheat flours. Cereal Chem. 77: 816-822 (2000)
7. Ross AS. Instrumental measurement of physical properties of cooked noodle Asian wheat flour noodles. Cereal Chem. 83: 42-51 (2006)
8. Rho KL, Seib PA, Chung OK, Deyoe CW. Noodles VII. Investigation of the surface firmness of cooked oriental noodles made from hard wheat flours. Cereal Chem. 65: 320-326 (1988)
9. Kruger JE, Hatcher DW, Anderson MJ. The effect of incorporation of rye flour on the quality of oriental noodles. Food Res. Int. 31: 27-35 (1999)
10. Black CK, Panozzo JF, Wright CL, Lim PC. Survey of white salted noodle quality characteristics in wheat landraces. Cereal Chem. 77: 468-472 (2000)
11. McCormick KM, Panozzo JF, Hong SH. A swelling power test for selecting potential noodle quality wheats. Aust. J. Agr. Res. 42: 317-323 (1991)
12. Crosbie GB. The relationship between starch swelling properties, paste viscosity and boiled noodle quality in wheat flours. J. Cereal Sci. 13: 145-150 (1991)
13. AACC. Approved Methods of the AACC. 8th ed. Method 30-25, 08-01, 44-15A, 54-21, 54-10. American Association of Cereal Chemists, St. Paul, MN, USA (1987)
14. Konik CM, Mikkelsen LM, Moss R, Gore PJ. Relationships between physical starch properties and yellow alkaline noodle quality. Starch-Stärke 46: 292-299 (1994)
15. Yun SH, Quail K. RVA Pasting properties of Australian wheat starches. Starch-Stärke 51: 274-280 (1999)
16. Yun SH, Rema G, Quail K. Instrumental assessments of Japanese white salted noodle quality. J. Sci. Food Agr. 74: 81-88 (1997)

17. Meigaard M, Civille GV, Carr BT. Sensory Evaluation Techniques. 2nd ed. CRC Press, Inc., Boca Raton, FL, USA. pp. 230-231 (1991)
18. Yun SH, Quail K, Moss R. Physicochemical properties of Australian wheat flour for white salted noodles. J. Cereal Sci. 23: 181-189 (1996)
19. Oh NH, Seib PA, Ward AB, Deyoe CW. Noodles IV. Influence of flour protein, extraction rate, particle size, and starch damage on the quality characteristics of dry noodles. Cereal Chem. 62: 441-446 (1985)
20. Hatcher DW, Symons SJ. Image analysis of Asian noodle appearance: Impact of hexaploid wheat with a red seed coat. Cereal Chem. 77: 388-391 (2000)
21. Zhao LF, Seib PA. Alkaline-carbonate noodles from hard winter wheat flour varying in protein, swelling power, and polyphenol oxidase activity. Cereal Chem. 82: 504-516 (2005)
22. Lee HJ, Shin MS. Comparison of the properties of wheat flours supplemented with various dietary fibers. Food Sci. Biotechnol. 15: 746-751 (2006)
23. Weller CL, Hwang KT, Schmidt BJ. Yield comparison of different methods of waxy fraction extraction from grain sorghum. Food Sci. Biotechnol. 15: 786-791 (2006)
24. Choi SJ, Chun SY, Yoo BS. Dynamic rheological comparison of selected gum solutions. Food Sci. Biotechnol. 15: 786-791 (2006)