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The effect of diverse treatments on biophysical characteristics of red kidney beans

Nafiseh Zamindar*[1], Leila Mosaffa[2], Moein Bashash[3], Mehdi Amoheidari[2] and Maryam Golabadi[4]

Department of Food Science and Technology,
Shahreza Branch, Islamic Azad University, Isfahan, 86145-311, Iran.
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ABSTRACT

The effect of line, tempering solution, temperature and soaking time were investigated on water absorption, splitting, and texture of two Iranian red kidney beans including Akhtar and Derakhshan to determine the best line and the best soaking conditions for industrial use. Akhtar line showed higher level of water absorption in comparison to Derakhshan line. Water absorption of unblanched red beans at 2.5 hour soaking was two times greater than water absorption of blanched ones for both lines ($p<0.05$). Acid solution made texture of Akhtar line softer than samples soaked in water and alkaline solution. In Derakhshan line, shear strength of samples treated with acid solution was lower than alkaline solution and water, respectively. Alkaline solution increased level of splitting in both lines ($p<0.05$).

Key words: Red kidney beans, Splitting, Shear strength, Soaking, Water absorption.

INTRODUCTION

Dry beans (*Phaseolus* spp. L.) have been cultivated for thousands of years, and have played an important role in the traditional diets of many regions throughout the world (Oboh *et al*., 1998; Meng and Ma, 2001; Rehman *et al*., 2001; Zamindar *et al*., 2013). Legumes are also a rich source of essential amino acids such as lysine and contain health-promoting phyto-chemicals, such as phytosterol, which has recently been associated with the prevention of breast cancer. Despite their superior nutritional qualities, legumes are underutilized in Europe. This may be due to the long soaking times (up to 16 h) and cooking times (up to 1 h) they require. As well as being inconvenient to both consumers and producers, long soaking times can potentially encourage harmful microbial proliferation (Gowen *et al*., 2007). Soaking allows water to be distributed among starch and protein fractions within the legume. As soaking proceeds, water penetrates the seed coat, travelling through the cotyledons and towards the center of the bean. Such water absorption causes the bean to become softer and uniform in texture (Gowen *et al*., 2007; Zamindar *et al*., 2013). High temperature-short time blanching has been shown to minimize nutrient losses in soy beans in comparison with lower temperature-longer time blanching (Gowen *et al*., 2007). Blanching also affects the process of hydration in legumes, and was found to increase hydration rates of kidney beans (Abu-Ghannam, 1998). While water alone aids in reducing cooking times, the use of dilute solutions of salts, acidulates, and/or alkali may be even more effective. Effective soaking solutions to reduce cooking times in beans (no micronization included) include ethylenediaminetetraacetic (EDTA) (Aguilera and Rivera, 1992; Bellido *et al*., 2006), sodium bicarbonate (Buckle and Sambudi, 1990; De leon *et al*., 1992), sodium tripolyphosphate (Scanlon *et al*., 1998), ethylenediaminetetraacetic (EDTA) a mixture of carbonates and phosphates (Scanlon *et al*., 1998; Al-Nouri and Siddiqi, 1982), sodium chloride (Ros and Rincon, 1991) and calcium chloride (Drake and Muehlbauer, 1985). Recent studies proposed the use of either a mixture of citric(10 g/l) and ascorbic acid (20 g/l) or EDTA (150 mg/l) pretreatments as the most effective tempering solutions for reducing hardness of lentils (Scanlon *et al*., 1998; Bellido *et al*, 2006).Tempering solutions containing a mixture of carbonates and phosphates have more reduced cooking times of micronized lentils (Zhao, 2000) and pea (Toews, 2001). An alkaline treatment consisting of 2 g/l sodium bicarbonate, 1 g/l sodium carbonate and 1 g/l dibasic sodium phosphate (pH 9.8) was shown to be a good tempering pretreatment to further reduced cooking times in peas (Toews, 2001; Bellido *et al*., 2006). The mechanisms by which salt solutions reduce cooking times in beans are yet not well understood. Chelating agents (i.e., EDTA) are thought to soften the texture of beans by facilitating cell wall separation during cooking through ion exchange and chelation mechanisms between monovalent cations (Na^+, K^+) in solution and divalent cations (Ca^{+2}, Mg^{+2}) in the middle lamella. In addition, salt solutions containing

*Corresponding author's e-mail: zamindar@ag.iut.ac.ir.
[1]Department of Food Science and Technology, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, 81551-39998, Iran.
[2]Department of Food Science and Technology, Shahreza Branch, Islamic Azad University, Isfahan, 86145-311, Iran.
[3]Department of Food Science and Technology, Damghan Branch, Islamic Azad University, Damghan, 36716-39998, Iran.
[4]Department of Agronomy and Plant Breeding, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, 81551-39998, Iran.

high ionic strength anions are thought to favour protein denaturation and thus shortening the cooking times of beans (Bellido *et al*., 2006). Very little information is available about Akhtar and Derakhshan red beans and the main aim of the present work was to study the effect of blanching, soaking temperature, and pretreatment solutions on water absorption and textural properties of these red kidney beans.

MATERIALS AND METHODS

Raw dry beans: Akhtar and Derakhshan red kidney bean (*Phaseolus vulgaris*) lines, used in this study were obtained from Khomein Agricultural Research Institute (Arak, Iran). Samples were stored in hermetically sealed bags at room temperature, in darkness (Gowen *et al*., 2007; Zamindar *et al*., 2013).The beans were cleaned from broken, small and split seeds, dust and other foreign materials. They were size-graded manually and divided into two groups. One group was blanched and then subjected to soaking treatments while the second group was directly subjected to soaking treatments. The chemicals used were reagent grade (Merck, Darmstadt, Germany).

Blanching procedure: Ten gram of beans was placed in a wire basket and immersed into a beaker containing tap water (pH: 7.5 ± 0.2) heated to 100 °C for 1.5 min. Then the samples were removed from the boiling water, drained, superficially dried, allowed to equilibrate with room temperature for 15 min and used in the following experiments (Gowen *et al*., 2007).

Determination of water intake during soaking: Soaking experiments were carried out for blanched and unblanched beans (Gowen *et al*., 2007). Water uptake data were obtained by soaking 10 g of beans in 80 ml of diverse solution systems such as, distilled water, a mixture of 10 g/l citric acid and 20 g/l ascorbic acid (pH 2.2), and a mixture of 2 g/l sodium bicarbonate, 1 g/l sodium carbonate, and 1 g/l dibasic sodium phosphate (pH 9.8). This selection of the tempering solutions was based on reported ability to reduce the cooking time and included a full range of pH values (Bellido *et al*., 2006). The samples maintained at the required temperature in thermostatically controlled water bath. The temperatures used included 25, 30, 40, 50, and 60 °C; and the soaking times were 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6 h. After soaking for each period, the beans were removed from the water bath, drained for 2 min, blotted dry to remove surface water and then weighed. The weight gain was then calculated as the difference between the measured weight at a given time and the original weight. No correction was made for the loss of solids leached into the soaking and cooking water (Taiwo *et al*., 1998). At this step all split and cracked beans were removed manually and weighed. Weight of damaged beans was devided to soaked beans' weight and multiplied by 100 to report the percentage of cracked beans caused by soaking and cooking treatments (Zamindar *et al*., 2013). All treatments were carried out on three sets of samples.

Texture evaluation: 20 gram of red kidney beans of lines Akhtar and Derakhshan were soaked in tempering solutions as described above (ratio 1:8 beans to solution). Soaking time was 6 h and the temperatures used included 40, 50, and 60 °C. This process was carried out separately for both blanched and unblanched beans. Puncture tests were performed by an Instron Universal Testing Machine (model 1140) in six replication. A cylindrical shape probe of 3 mm end diameter was used in puncture tests. An aluminum plate with dimensions of 10×10 cm^2 and thickness of 1.3 cm and a hole of 5 mm diameter in its center was supported on the Instron base. The cutter was lowered at the speed of 200 $mmmin^{-1}$. The orientation of each bean was kept uniform during operation. Beans were placed on their side with the hillium pointing away from the observer. The cutting implement was allowed to travel the thickness of the bean, cutting the sample transversely through the center at the helium, stopping 1 mm away from the plate. Since variation in texture was substantial, six legumes were chosen as a representative sample of the soaking population to undergo compression at each sampling point. Red bean hardness was defined as shear strength. The shearing strength determines the degree to which the bean cells are held together.

$$S= F/\pi dt$$

Where "s" is the shearing strength gf/cm^2, "F" is shearing force (maximum force required to shear the bean, the peak of the force-deformation curve) recorded in gf per sample, "d" is the diameter of cylindrical probe (cm) and "t" is the thickness of each bean (cm) (Zamindar *et al*., 2013; Taiwo *et al*., 1998; Mohsenin, 1986).

Experimental design: The experiment was conducted in factorial form, using a completely randomized design with three replications to study the effects of blanching, tempering solutions, soaking time and temperature on water absorption and splitting percentage. The first factor was blanching, the second factor was tempering solution (distilled water, acid solution and alkaline solution), the third factor was soaking temperature (25, 30, 40, 50, 60°C), and the fourth one was soaking time (0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5, 5.5, 6 h). For each replication 10 g of seeds were used. LSD test was performed to compare the means. The significance level 'a' for these comparisons was set to 0.05. Data were analyzed by SAS (version 8.02, SAS Institute Inc, 2001, Cary, NC). Experimental design for texture analysis was a factorial experiment including three factors arranged in a completely randomized design with six replications. The effect of blanching, soaking temperature (40, 50, 60°C), and tempering solution (distilled water, acid solution and alkaline solution) on texture were studied in this design (Zamindar *et al*., 2013).

RESULTS AND DISCUSSION

Effect of diverse parameters on hydration: The effects of all main parameters such as blanching, solution, temperature, and time of soaking on hydration of both lines were significant at $p<0.05$. All two way interactions were significant except interaction of tempering solution and soaking time ($p<0.05$). All three way interactions were insignificant ($p<0.05$) except the interaction of blanching×tempering solution×solution temperature. Four way interactions were not significant ($p<0.05$). According to Table 1, blanching reduced the hydration of red kidney beans ($p<0.05$), hydration of unblanched red beans was two times greater than blanched ones. Raising the soaking temperature and soaking time caused increasing in water absorption significantly in both lines of red kidney beans. In addition, increasing the soaking time had the same effect on both lines (Table 1). This agrees with the reports of other researchers on different types of beans (Kinyanjui *et al*., 2015; Fernandes *et al*., 2010; Taiwo *et al*., 1998).

The two way interaction of tempering solution and temperature on hydration was the highest in alkaline solution at 60°C for both lines but the difference between different solutions at 60°C was not significant ($p<0.05$). For Derakhshan line all kinds of solutions showed good level of water absorption at 50 °C without significant difference in splitting, but for Akhtar line 60°C was better for more water absorption in all kinds of solutions at $p<0.05$ (Table 2). Results given in Table 3 showed that to reach 90% water absorption in Akhtar line at 60, 50, and 40 °C 1.5, 2.5 and 5 hour soaking time would be required. Furthermore, at 25°C and 30°C the hydration was 73.39 and 78.39% at the end of soaking time (6 h), respectively. Results given in Table 4 showed that to reach 90% water absorption in Derakhshan line at 60 and 50°C, 2 and 2.5 h soaking time would be required. Furthermore, at 25, 30 and 40°C the hydration was 70.28, 70.83 and 88.94% at the end of soaking time (6 h), respectively.

Interaction of blanching, tempering solution and temperature on water absorption and splitting for both lines were shown in Table 5. It is evident that at 50 and 60°C the unblanched samples in all tempering solutions showed the highest hydration with no significant difference ($p<0.05$) in both Akhtar and Derakhshan lines. Hydration of unblanched red beans in water solution at temperatures of 25, 30 and 40°C was significantly lower than 50 and 60°C for both lines ($p<0.05$). Hydration of blanched beans in all kinds of solutions was less than hydration of blanched beans at temperatures less than 60°C for both lines. Hydration of blanched red beans soaked in alkaline solution at 60°C was

Table 1: Effect of blanching, solution, temperature and time on hydration and splitting of Akhtar and Derakhshan lines.

	Main Factors	Akhtar Line		Derakhshan Line	
		Means of splitting(%)	Means of hydration(%)	Means of splitting(%)	Means of hydration(%)
Blanching	Blanched	$1.70^{A}\pm0.02$	$53.85^{B}\pm0.4$	$1.46^{B}\pm0.02$	$46.58^{B}\pm0.4$
	Unblanched	$1.71^{A}\pm0.01$	$100.20^{A}\pm0.18$	$1.83^{A}\pm0.02$	$101.94^{A}\pm0.18$
Solution	Distilled water	$1.13^{B}\pm0.01$	$73.54^{B}\pm0.39$	$1.92^{A}\pm0.02$	$73.26^{B}\pm0.42$
	Acid solution	$1.33^{B}\pm0.01$	$78.34^{A}\pm0.39$	$1.13^{B}\pm0.01$	$70.25^{C}\pm0.39$
	Alkaline solution	$2.64^{A}\pm.0.02$	$79.20^{A}\pm0.38$	$1.88^{A}\pm0.02$	$79.27^{A}\pm0.43$
Temperature	25 °C	$1.50^{B}\pm0.01$	$56.40^{E}\pm0.4$	$1.80^{B}\pm0.02$	$54.52^{D}\pm0.44$
	30°C	$2.03^{A}\pm0.02$	$59.27^{D}\pm0.38$	$1.15^{C}\pm0.01$	$55.16^{D}\pm0.43$
	40°C	$1.53^{B}\pm0.01$	$71.03^{C}\pm0.36$	$1.95^{A}\pm0.02$	$66.31^{C}\pm0.38$
	50°C	$1.96^{A}\pm0.01$	$94.81^{B}\pm0.3$	$1.84^{A}\pm0.02$	$94.90^{B}\pm0.3$
	60°C	$1.49^{B}\pm0.01$	$103.62^{A}\pm0.23$	$1.48^{B}\pm0.02$	$100.41^{A}\pm0.26$
Time	0.5 h	$1.13^{C}\pm0.01$	$38.44^{J}\pm0.3$	$0.57^{E}\pm0.01$	$38.25^{K}\pm0.3$
	1 h	$1.13^{C}\pm0.01$	$50.66^{I}\pm0.34$	$0.57^{E}\pm0.01$	$50.02^{J}\pm0.34$
	1.5 h	$1.21^{C}\pm0.01$	$60.56^{H}\pm0.36$	$0.82^{D}\pm0.01$	$59.15^{I}\pm0.37$
	2 h	$1.28^{B}\pm0.01$	$68.43^{G}\pm0.37$	$1.07^{D}\pm0.01$	$67.55^{H}\pm0.4$
	2.5 h	$1.59^{B}\pm0.02$	$74.12^{F}\pm0.37$	$1.32^{D}\pm0.01$	$73.10^{G}\pm0.4$
	3 h	$1.71^{B}\pm0.02$	$79.53^{E}\pm0.37$	$1.70^{C}\pm0.01$	$75.65^{F}\pm0.44$
	3.5 h	$1.91^{B}\pm0.02$	$83.92^{D}\pm0.36$	$2.00^{B}\pm0.02$	$81.58^{E}\pm0.4$
	4 h	$2.03^{A}\pm0.02$	$87.91^{C}\pm0.36$	$2.21^{B}\pm0.02$	$84.57^{D}\pm0.4$
	4.5 h	$2.11^{A}\pm0.02$	$91.95^{B}\pm0.34$	$2.29^{B}\pm0.02$	$87.08^{C}\pm0.39$
	5 h	$2.11^{A}\pm0.02$	$93.90^{B}\pm0.33$	$2.38^{B}\pm0.02$	$89.53^{B}\pm0.38$
	5.5 h	$2.11^{A}\pm0.02$	$96.48^{A}\pm0.31$	$2.38^{A}\pm0.02$	$91.44^{A}\pm0.37$
	6 h	$2.11^{A}\pm0.02$	$98.43^{A}\pm0.3$	$2.42^{A}\pm0.02$	$93.18^{A}\pm0.36$

Means having the same letter within each property are not significantly different using LSD test at $P<0.05$.

Table 2: Interaction of tempering solution and temperature on water absorption and splitting for Akhtar and Derakhshan lines.

Akhtar line			Derakhshan line		
solution × temperature	**Water absorption (%)**	**Splitting (%)**	**solution × temperature**	**Water absorption (%)**	**Splitting (%)**
water×25°C	56.47^{E} ±0.4	1.19^{A} ±0.01	water×25°C	53.72^{DE} ±0.42	1.6^{A} ±0.02
water×30°C	55.15^{E}±0.38	1.13^{A} ±0.02	water×30°C	51.58^{E} ±0.43	1.17^{A} ±0.01
water×40°C	62.58^{DE}± 0.35	1.02^{A}±0.01	water×40°C	66.43^{C} ±0.33	2.07^{A}±0.02
water×50°C	91.71^{B}±0.33	0.86^{A}±0.01	water×50°C	94.79^{AB} ±0.31	2.3^{A}±0.02
water×60°C	101.8^{AB}±0.19	1.44^{A}±0.02	water×60°C	99.79^{AB}±0.33	2.47^{A}±0.02
acid×25°C	55.97^{E}±0.42	0.82^{A}±0.01	acid×25°C	51.99^{DE} ±0.43	1.95^{A}±0.02
acid30°C	63.88^{DE}±0.37	1.73^{A}±0.02	acid30°C	49.76^{E}±0.4	0.61^{A}±0.01
acid×40°C	73.86^{CD}±0.38	0.85^{A}±0.01	acid×40°C	64.03^{CD} ±0.36	1.82^{A}±0.01
acid×50°C	94.94^{AB}±0.3	1.87^{A}±0.01	acid×50°C	89.75^{B} ±0.28	0.8^{A}±0.01
acid×60°C	103.1^{AB}±0.22	1.38^{A}±0.01	acid×60°C	95.72^{AB} ±0.2	0.49^{A}±0.01
alkaline×25°C	56.78^{E}±0.39	2.5^{A}±0.01	alkaline×25°C	57.86^{CDE} ±0.46	1.86^{A}±0.01
alkaline×30°C	58.81^{E}±0.37	3.24^{A}±0.02	alkaline×30°C	64.14^{CD} ±0.45	1.67^{A}±0.01
alkaline×40°C	76.67^{C}±0.34	2.72^{A} ±0.02	alkaline×40°C	68.47^{C}±0.44	1.97^{A} ±0.02
alkaline×50°C	97.78^{AB}±0.37	3.14^{A} ±0.02	alkaline×50°C	100.2^{AB}±0.3	2.43^{A} ±0.02
alkaline×60°C	106^{A}±0.24	1.63^{A} ±0.02	alkaline×60°C	105.7^{A}±0.24	1.47^{A} ±0.02

Means having the same letter within each property are not significantly different using LSD test at P<0.05.

Table 3: Interaction of temperature and time on water absorption in Akhtar line.

temperature× time	**Water absorption (%)**	**temperature× time**	**Water absorption (%)**
25°C ×0.5h	23.61^{Z}± 0.22	40°C ×3.5h	75.44^{JKLMN}±0.32
25°C ×1h	34.39^{Z}±0.29	40°C×4h	80.78^{HIJK} ±0.3
25°C ×1.5h	41.83^{Z} ±0.33	40°C ×4.5h	85.83^{GHIJ}±0.27
25°C ×2h	49.22^{XYZ} ±0.38	40°C ×5h	90.89^{FGH} ±0.23
25°C ×2.5h	54.28^{UVWXY} ±0.4	40°C ×5.5h	96.33^{EFG}±0.19
25°C ×3h	58.22^{TUVWX} ±0.41	40°C ×6h	99.78^{EFG} ±0.17
25°C ×3.5h	62.00^{RSTUVW} ±0.42	50°C ×0.5h	45.33^{STUVWX}±0.32
25°C ×4h	64.67^{PQRSTU} ±0.42	50°C ×1h	59.78^{LMNOPQR}±0.32
25°C r×4.5h	73.22^{LMNOPQR} ±0.42	50°C ×1.5h	72.94^{IJKL}±0.28
25°C ×5h	70.06^{MNOPQRST} ±0.42	50°C ×2h	83.39^{GHIJ}±0.27
25°C ×5.5h	72.00^{LMNOPQR} ±0.41	50°C ×2.5h	92.22^{DEFG}±0.22
25°C ×6h	73.39^{LMNOPQR} ±0.41	50°C ×3h	100.61^{BCDEF}±0.16
30°C×0.5h	28.17^{Z}±0.25	50°C ×3.5h	106.67^{ABCDE}±0.11
30°C ×1h	36.50^{YZ} ±0.31	50°C×4h	111.6^{ABC}±0.07
30°C ×1.5h	43.67^{WXYZ} ±0.34	50°C ×4.5h	113.50^{ABC}±0.07
30°C ×2h	50.72^{UVWXY} ±0.37	50°C ×5h	115.94^{ABC}±0.29
30°C ×2.5h	55.11^{STUVWX} ±.037	50°C ×5.5h	117.39^{AB}±0.23
30°C ×3h	59.39^{QRSTUV} ±0.38	50°C ×6h	118.33^{TUVWX}±0.14
30°C×3.5h	63.28^{OPQRST} ±0.38	60°C ×0.5h	58.28^{KLMNO}±0.11
30°C ×4h	67.72^{MNOPQRS} ±0.37	60°C ×1h	78.22^{GHI}±0.08
30°C ×4.5h	71.22^{KLMNOPQ} ±0.34	60°C ×1.5h	93.17^{DEFG} ±0.07
30°C ×5h	75.28^{KLMNO} ±0.36	60°C ×2h	100.39^{CDEF}±0.07
30°C ×5.5h	78.39^{IJKLM}±0.34	60°C ×2.5h	106.06^{ABCDE}±0.07
30°C ×6h	81.89^{IJKLM} ±0.32	60°C ×3h	109.94^{ABCD} ±0.07
40°C ×0.5h	36.83^{YZ}±0.32	60°C ×3.5h	112.22^{ABC}±0.07
40°C ×1h	44.44^{VWXYZ}±0.36	60°C×4h	114.78^{ABC}±0.07
40°C ×1.5h	51.22^{TUVWX}±0.38	60°C ×4.5h	116.00^{ABC}±0.07
40°C ×2h	58.44^{RSTUV}±0.38	60°C ×5h	117.33^{ABC}±0.07
40°C ×2.5h	62.94^{NOPQRST}±0.37	60°C ×5.5h	118.33^{AB}±0.07
40°C ×3h	69.50^{KLMNOP}±0.35	60°C ×6h	118.78^{A}±0.07

Means having the same letter within each property are not significantly different using LSD test at P<0.05.

Table 4: Interaction of temperature and time on water absorption in Derakhshan line.

temperature× time	Water absorption (%)	temperature× time	Water absorption (%)
25°C ×0.5h	23.50^{Z} ±.023	40°C ×3.5h	70.61^{MNOP} ±0.37
25°C ×1h	32.89^{Z}±0.3	40°C×4h	73.89^{KLMNO} ±0.36
25°C ×1.5h	41.39^{YZ} ±0.37	40°C ×4.5h	77.89^{JKLMN} ±0.33
25°C ×2h	50.22^{UVWXY} ±0.45	40°C ×5h	81.67^{IJKLM} ±0.31
25°C ×2.5h	55.17^{RSTUVWX} ±0.46	40°C ×5.5h	85.33^{HIJK}±0.28
25°C ×3h	57.78^{QRSTUVW} ±0.47	40°C ×6h	88.94^{FGHIJ}±0.25
25°C ×3.5h	60.50^{PQRSTUV} ±0.47	50°C ×0.5h	46.94^{WXYZ}±0.31
25°C ×4h	62.78^{OPQRST} ±0.47	50°C ×1h	61.78^{OPQRSTU}±0.30
25°C r×4.5h	64.44^{OPQRS} ±0.46	50°C ×1.5h	72.00^{LMNOP}±0.28
25°C ×5h	66.83^{NOPQR} ±0.45	50°C ×2h	82.94^{IJKL}±0.26
25°C ×5.5h	68.50^{NOPQ} ±0.43	50°C ×2.5h	90.67^{FGHI}±0.22
25°C ×6h	70.28^{MNOP} ±0.42	50°C ×3h	99.50^{DEF}±0.17
30°C×0.5h	27.72^{Z}±0.25	50°C ×3.5h	105.78^{BCDE}±0.13
30°C ×1h	37.61^{Z} ±0.33	50°C×4h	110.89^{ABCD}±0.10
30°C ×1.5h	44.00^{XYZ} ±0.39	50°C ×4.5h	113.94^{ABC}±0.07
30°C ×2h	49.28^{VWXYZ} ±0.43	50°C ×5h	116.83^{AB}±0.06
30°C ×2.5h	53.56^{STUVWXY} ±0.44	50°C ×5.5h	118.33^{A}±0.06
30°C ×3h	56.94^{QRSTUVW} ±0.45	50°C ×6h	119.28^{A}±0.06
30°C×3.5h	59.89^{PQRSTUV} ±0.46	60°C ×0.5h	57.83^{QRSTUVW}±0.3
30°C ×4h	61.89^{OPQRSTU} ±0.46	60°C ×1h	73.22^{KLMNO} ±0.24
30°C ×4.5h	64.56^{OPQRS} ±0.46	60°C ×1.5h	87.11^{GHIJ}±0.19
30°C ×5h	66.89^{NOPQR} ±0.45	60°C ×2h	98.17^{EFG} ±0.14
30°C ×5.5h	68.78^{NOPQ} ±0.45	60°C ×2.5h	104.00^{CDE}±0.09
30°C ×6h	70.83^{LMNOP} ±0.44	60°C ×3h	113.4^{ABC}±0.49
40°C ×0.5h	35.28^{Z}±0.31	60°C ×3.5h	111.17^{ABCD}±0.07
40°C ×1h	44.61^{XYZ} ±0.38	60°C×4h	113.44^{ABC}±0.007
40°C ×1.5h	51.28^{TUVWXY} ±0.41	60°C ×4.5h	114.61^{ABC}±0.06
40°C ×2h	57.17^{QRSTUVW} ±0.41	60°C ×5h	115.44^{ABC}±0.06
40°C ×2.5h	62.11^{OPQRSTU} ±0.4	60°C ×5.5h	116.28^{AB}±0.07
40°C ×3h	66.94^{NOPQR} ±0.38	60°C ×6h	116.61^{AB}±0.07

Means having the same letter within each property are not significantly different using LSD test at P<0.05.

similar to hydration of unblanched beans at 60°C for Akhtar line. For Akhtar line, hydration of unblanched red beans in acid and alkaline solutions at temperatures of 25 and 30°C was significantly lower than 50 and 60°C ($p<0.05$). For Derakhshan line, hydration of unblanched red beans in acid and alkaline solutions at 25°C was significantly lower than 50 and 60°C ($p<0.05$), indicating that for unblanched Derakhshan beans, Alkaline solution may cause good level of hydration even at 30°C. In blanched samples of Derakhshan and akhtar lines at each level of temperature, alkaline solution was more effective in hydration and caused higher water absorption compare to water or acid solution and the results are in agreement with Kinyanjui *et al*. (2015). Fernandes *et al*. (2010) reported that soaking also reduced the level of oligosaccharides especially when $NaHCO_3$ solution was used.

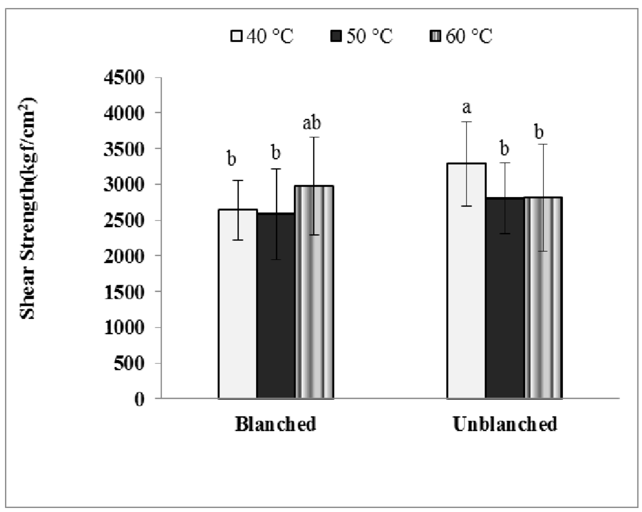

Fig 1: Interaction of blanching and temperature on shear strength of Akhtar line (P<0.05)

Effect of diverse parameters on shear strength: The effect of blanching on shear strength in Akhtar line was significant ($p<0.05$), unblanched beans showed higher shear strength at 40 and 50°C and less shear strength at 60°C (Fig.1). Therefore increasing soaking temperature of unblanched Akhtar beans decreased shear strength but the same rule did not stand for blanched samples. The effect of tempering solution on shear strength was significant ($p<0.05$), acid solution made texture of Akhtar line softer than samples soaked in water and alkaline solution. The effect of temperature and two way interaction of blanching and tempering solution and three way interactions on shear

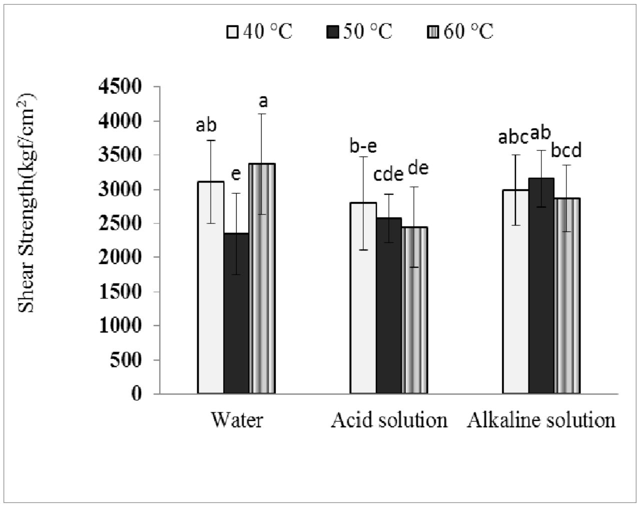

Fig 2: Interaction of solution, temperature on shear strength of Akhtar line (P<0.05)

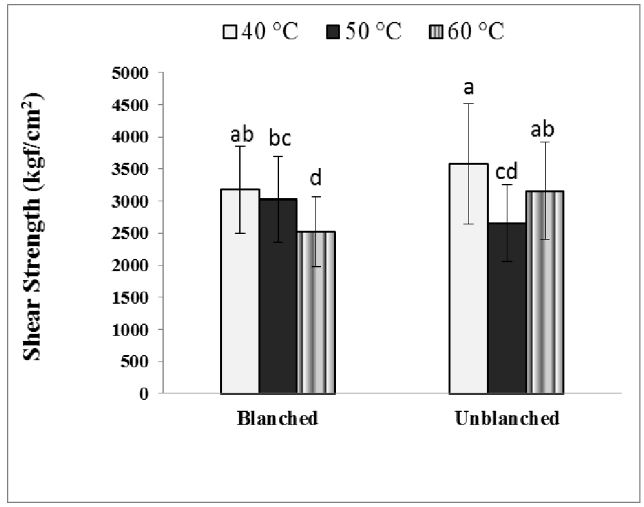

Fig 3: Interaction of blanching and temperature on shear strength of Derakhshan line (P<0.05)

Table 5: Interaction of blanching, solution and temperature on water absorption and splitting for Akhtar and Derakhshan lines.

Akhtar line			Derakhshan line		
blanching × solution× temperature	**Water absorption (%)**	**Splitting (%)**	**blanching × solution× temperature**	**Water absorption (%)**	**Splitting (%)**
blanched × water×25°C	21.53 ^{LM} ±0.2	0.00^{C} ±0	blanch × water×25°C	14.47^{K} ±0.08	1.38^{AB}±0.03
blanched × water×30°C	19.92 ^{M}±0.12	0.61^{BC} ±0.01	blanch × water×30°C	10.61^{K} ±0.04	0.66^{B}±0.01
blanched × water×40°C	33.81^{JK}± 0.2	0.82^{ABC}±0.01	blanch × water×40°C	40.50^{I} ±0.24	1.78^{AB}±0.01
blanched × water×50°C	77.31 ^{H}±0.4	0.49^{BC} ±0.01	blanch × water×50°C	80.22^{GH} ±0.36	1.77^{AB}±0.01
blanched × water×60°C	97.08 ^{BCDEF}±.2	1.15^{ABC} ±0.01	blanch × water×60°C	90.44^{EFG} ±0.44	0.82^{B}±0.01
blanched × acid×25 °C	18.06^{M} ±0.09	0.57^{BC} ±0.01	blanch × acid×25 °C	12.83^{K} ±0.09	2.18^{AB}±0.02
blanched × acid×30°C	32.11^{JKL}±0.19	2.32^{ABC} ±0.02	blanch × acid×30°C	12.11^{K}±0.07	1.22^{AB}±0.02
blanched × acid×40°C	42.89^{IJ}±0.24	0.51^{BC} ±0.01	blanch × acid×40°C	31.89^{IJ} ±0.18	1.46^{AB}±0.01
blanched × acid×50°C	80.58^{GH}±0.33	2.51^{ABC} ±0.01	blanch × acid×50°C	75.22^{H} ±0.32	0.89^{AB}±0.01
blanched × acid×60°C	92.5^{EFG}±0.25	0.83^{ABC} ±0.01	blanch × acid×60°C	87.44^{FGH} ±0.25	0.00^{B}±0
blanched × alkaline×25°C	21.58^{LM}±0.11	2.59^{ABC} ±0.01	blanch × alkaline×25°C	14.50^{K} ±0.09	1.95^{AB}±0.01
blanched × alkaline×30°C	25.69^{KLM}±0.15	3.54^{AB}±0.02	blanch × alkaline×30°C	21.78^{JK} ±0.13	2.19^{AB}±0.01
blanched × alkaline×40°C	51.64^{I}±0.32	4.25^{A} ±0.01	blanch × alkaline×40°C	26.97^{J} ±0.16	2.36^{AB}±0.02
blanched × alkaline×50°C	86.92^{FGH}±0.35	3.9^{AB} ±0.03	blanch × alkaline×50°C	84.28^{FGH}±0.33	3.22^{AB}±0.03
blanched × alkaline×60°C	106.2^{ABC}±0.32	1.38^{ABC} ±0.02	blanch × alkaline×60°C	95.53^{CDEF} ±0.29	0.0^{B}±0.00
unblanched× water×25°C	91.42^{EFG}±0.21	2.38^{ABC} ±0.01	unblanched× water×25°C	92.97^{DEF}±0.22	1.82^{AB}±0.01
unblanched× water×30°C	90.39^{EFG}±0.17	1.64^{ABC} ±0.01	unblanched× water×30°C	92.56^{DEF} ±0.18	1.67^{AB}±0.01
unblanched× water×40°C	91.36^{EFG}±0.15	1.23^{ABC} ±0.01	unblanched× water×40°C	92.36^{DEFG} ±0.16	2.35^{AB}±0.02
unblanched× water×50°C	106.1^{ABC}±0.13	1.23^{ABC} ±0.01	unblanched× water×50°C	109.4^{AB}±0.15	2.82^{AB}±0.02
unblanched× water×60°C	106.6^{ABC}±0.09	1.74^{ABC} ±0.02	unblanched× water×60°C	109.1^{AB}±0.11	4.13^{A}±0.01
unblanched × acid×25 °C	93.89^{DEF}±0.25	1.07^{ABC} ±0.01	unblanched × acid×25 °C	91.14^{EFG}±0.23	1.72^{AB}±0.01
unblanched × acid×30°C	95.64^{CDEF}±0.21	1.15^{ABC} ±0.01	unblanched × acid×30°C	87.42^{FGH}±0.17	0.00^{B}±0.00
unblanched × acid×40°C	104.8^{ABCD}±0.18	1.19^{ABC} ±0.01	unblanched × acid×40°C	96.17^{CDEF}±0.12	2.189^{AB}±0.01
unblanched × acid×50°C	109.3^{A}±0.18	1.23^{ABC} ±0.01	unblanched × acid×50°C	104.3^{ABCD}±0.12	0.71^{B}±0.01
unblanched × acid×60°C	113.6^{A}±0.12	1.94^{ABC} ±0.01	unblanched × acid×60°C	104.0^{ABCD}±0.08	0.99^{AB}±0.01
unblanched× alkaline×25°C	91.97^{EFG}±0.22	2.42^{ABC} ±0.01	unblanched× alkaline×25°C	101.2^{BCDE}±0.19	1.77^{AB}±0.01
unblanched × alkaline×30°C	91.92^{EFG}±0.2	2.93^{ABC} ±0.02	unblanched × alkaline×30°C	106.5^{ABC}±0.2	1.15^{AB}±0.01
unblanched × alkaline×40°C	101.7^{ABCDE}±0.11	1.19^{ABC} ±0.01	unblanched × alkaline×40°C	110.0^{AB}±0.14	1.58^{AB}±0.01
unblanched × alkaline×50°C	108.6^{AB}±0.11	2.38^{ABC} ±0.01	unblanched × alkaline×50°C	116.1^{A}±0.14	1.63^{AB}±0.01
unblanched × alkaline×60°C	105.8^{ABCD}±0.1	1.88^{ABC} ±0.01	unblanched × alkaline×60°C	115.9^{A}±0.11	2.94^{AB}±0.02

Means having the same letter within each property are not significantly different using LSD test at P<0.05.

strength of Akhtar line were not significant ($p<0.05$). Two way interaction of solution and temperature (Fig.2) showed that acid solution at 50 and 60°C and water at 50°C caused lower shear strength and softer texture in red beans ($p<0.05$). For Derakhshan line, the effect of blanching and two way interactions of blanching and solution, solution and temperature and three way interactions on shear strength were not significant ($p<0.05$). In Derakhshan line, shear strength of acid solution samples was lower than alkaline solution and water, respectively ($p<0.05$). For Derakhshan blanched samples increasing temperature decreased shear strength while unblanched beans showed softer texture at 50°C (Fig. 3).

Effect of diverse parameters on splitting: The effect of line, soaking time and temperature, and tempering solution on splitting were significant ($p<0.05$) for both Akhtar and Derakhshan lines. Blanching had no significant effects on splitting of Akhtar line, but alkaline solution increased splitting of Akhtar beans. Splitting reached the level of 2% after 3.5h soaking (Table 1). The maximum level of splitting (4.25%) was caused by blanching beans and using alkaline solution at 40°C for soaking (Table 5). According to table 1, blanching decreased splitting of Derakhshan but water and alkaline solution caused higher level of spillitting for this line. Splitting reached the level of 2% after 3.5h soaking (Table 1). The maximum level of splitting (4.13%) was observed in unblanched Derakhshan beans soaked in water at 60°C for soaking (Table 5). Results were in agreement with earlier observations on similar samples (Bellido *et al*., 2006).

CONCLUSION

In Akhtar line unblanching caused higher water absorption without splitting increase. Comparing the data relating to hydration and splitting, in Akhtar line soaking the unblanched beans at 60°C for 2.5 h caused high water absorption and low splitting and low shear strength in acid solution, similar conditions existfor unblanched Akhtar beans soaked in water at 50°C for 3.5 h. For Derakhshan line unblanched samples soaked in water, acid or alkaline solutions at 50°C for 3 h showed high level of water absorption and low level of shear strength without significant difference in splitting ($p<0.05$).

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