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Pearson's Correlation Between Physico-chemical Aspects of Wheat Flour and Quality Attributes of Cookies

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Abstract. In this study, we investigated various physico-chemical properties of wheat and evaluated their correlation with cookie attributes. Results showed that damaged starch in wheat varieties ranged from 6.28 to 10.97%. SDS-sed. and AWRC values were recorded as 18.20-30.50 mL and 43.91-66.85%, respectively. WSRC, SOCSRC, SUCSRC and LASRC values varied over a wide range as 50.83-69.64%, 56.66-82.03%, 75.79-106.97% and 79.43-121.20%, respectively. Physical analyses of cookies made with wheat varieties indicated 25.20-26.60 cm width, 5.80-6.40 cm thickness and 39.38-45.86 spread factor and 2.17-3.91 kg hardness. Important correlations were reported between water absorption and SDS sedimentation (r= 0.912*). Likewise, a positive relationship was found between damaged starch and SUCSRC (r= 0.985**).Spread factor was found to be negatively correlated to ash (r= -0.977**), protein(r= -0.892*), SOCSRC (r= -0.952*), WSRC (r= -0.892*) and hardness (r= -0.990**).Correlation studies indicated that physico-chemical characteristics of flour are imperative in the evaluation of cookie making quality.

Keywords: damaged starch, SDS-sedimentation test,alkaline water retention capacity, cookies quality, correlation studies

Introduction

Physico-chemical characteristics of flour are important to govern dough rheology and predict flour quality to develop a range of bakery products. Various predictive methods closely associated with quality of wheat flour are commonly employed in wheat breeding programs for quality assessment of wheat flour. These methods are easy to conduct utilizing only few gram sample (Colombo *et al*., 2008). Pragmatically, damaged starch is produced when starch granules are mechanically damaged during milling. Degree of damage vary and depends on kernel hardness and severity of milling technique. It absorbs more water than non-damaged and more liable to enzymatic hydrolysis (El-Porai *et al*., 2013). Higher level of DS is detrimental to quality of soft wheat products particularly cookies and cakes (Barrera *et al*., 2007).

Solvent retention capacity (SRC) ascribed as flour ability to hold a set of four different solutions *i.e.* 5% sodium carbonate, 50% sucrose, 5% lactic acid and deionized water. It is a rapid, small scale test developed to evaluate the role of all functional components in end product quality for applications of soft wheat (Kang *et al*., 2014). Generally, sodium carbonate SRC (SOCSRC) is related to damaged starch, sucrose SRC (SUCSRC) linked to pentosans and gliadin, lactic acid SRC (LASRC) to glutenin characteristics and water SRC (WSRC) associated with all the four components as given earlier by Guttieri *et al*. (2001) and Geng *et al*. (2012).

Wheat quality usually reflects its suitability for a certain purpose, intended use and particular end product (Amjad *et al.*, 2010). It is of great importance for baking industry as it demands flour of desirable functionality to develop different products (Fustier *et al*., 2009a). Wheat qualityis immensely important for processor and he likes consistent quality according to specific product. In this perspective, present research was planned to explore numerous physico-chemical parameters and identify suitable varieties in relation to cookie making quality. Moreover, correlation of different physico-chemical parameters with cookie quality was also evaluated.

Materials and Methods

Procurement of raw materials. Commercially available varieties of wheat (*Triticum aestivum* L.) were procured from Wheat Research Institute, Ayub Agricultural Research Institute, Faisalabad, Punjab and Wheat Research Institute Sakrand, Nawabshah, Sindh, Pakistan.

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All chemicals and reagents (analytical grade) were purchased from Merck and local market.
Wheat milling. Tempering of wheat grains was carried out at 15.5% moisture level and tempered wheat was milled using Brabender Quadrumate Senior Mill according to AACC (2000) method No. 26-21A in order to obtain straight grade flour comprisingof break and reduction flour fractions.

Chemical analyses. Chemical analyses of straight grade flour obtained from each variety were conducted by their respective methods given in AACC (2000). Moreover, wet gluten and dry gluten of wheat flour were determined through Glutomatic (Pertin GM-2200; Sweden) by AACC method no. 38-12A (AACC, 2000). Wheat flour was analyzed for damaged starch (method no. 76-30A), SDS- sedimentation test (method no. 56-70) and AWRC (method no. 56-10) as mentioned in AACC (2000). SRC values of wheat flour were recorded according to method no. 56-11 (AACC, 2000) with minor changes as suggested by Ram and Singh (2004) and Pasha *et al.* (2009). 1 g flour sample instead of 5 g was added to 15 mL tubes with conical bottoms. The sample was dispersed in solvent (5 mL) and kept on a vortex mixer for 20 min with intermittent stirring (at 5, 10, 15, and 20 min) followed by centrifugation at 1000×g for 15 min.

Rheological properties. Rheological properties of wheat flour were determined through Farinograph (Brabender D-4100; Germany) according to method no. 54-21 as described in AACC (2000).

Preparation and analyses of cookies. Cookies were prepared using straight grade flour obtained from wheat varieties according to method no. 10-50D (AACC, 2000). Spread factor was calculated by dividing the width with thickness of six cookies at a time according to AACC (2000). Hardness values of cookies were determined according to the method of Piga *et al*. (2005) using Texture Analyzer (TA-XT2, Plus, Stable Microsystems, Surrey, UK). Sensory quality of cookies was assessed by adopting the method of Meilgaard *et al*. (2007).

Statistical analysis. Data from all experiments was collected in triplicate and reported as mean± standard error. Significant variations within wheat varieties were evaluated through Analysis of Variance under Completely Randomized Design according to method described by Montgomery (2008) using different statistical software like SPSS version (version 13, 2004) and Minitab (version 11.2, 1996). Correlation of different parameters was determined by Pearson's correlation coefficient.

Results and Discussion

Chemical composition. Present results show that chemical properties varied over wide ranges for moisture, ash, fat, fibre, protein and NFE content as 8.50-10.78, 0.33-0.83, 1.34-1.49, 0.38-0.52, 9.85-13.75, 72.82-79.58% (Table 1). Since, high amount of ash represents the contamination of bran in wheat flour implying that high ash content in wheat varieties may adversely affect cookie quality. From nutrition viewpoint, TD-1 and Benazir-13 had highest protein content, but these may find their potential application for bread making. Above all, AARI-11 having lower protein content acquired eminent interest and it is supported by the fact that,

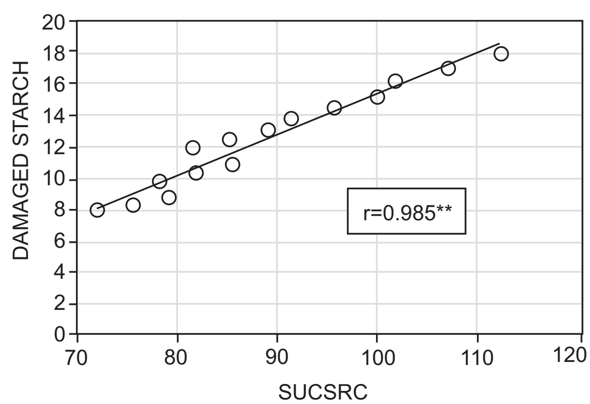

Fig. 1. Correlation between damaged starch and SUCSRC

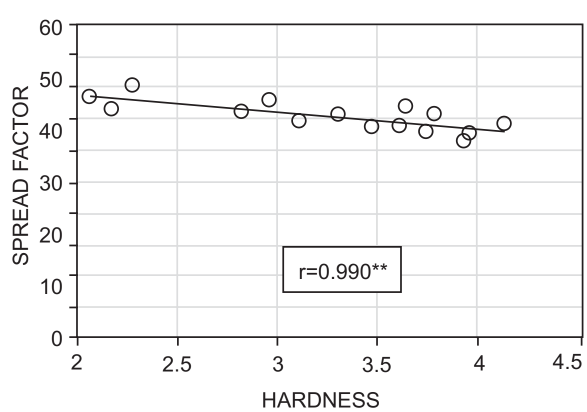

Fig. 2. Correlation between spread factor and hardness

cookie quality is related to low protein content (soft wheat). Present results are in good agreement with data obtained by various authors (Iqbal *et al*., 2015; Amjad *et al*., 2010). A wide range for wet gluten and dry gluten in wheat flour was observed from 24.68 to 36.40% and from 7.12 to 11.84%, respectively. According to studies of Barrera *et al*. (2007) as well as of Kumar *et al*. (2013), wet gluten in different wheat cultivars varied between 24.10 and 33.60%. Gluten quality is usually influenced by genetics, growing conditions, milling(Hazelton *et al*., 2004) as well as genetic potentiality to accumulate proteins in seed.

Damaged starch. Statistical data indicated that damaged starch had significantly (P<0.01)more variability due to wheat varieties. A broad range of variations was observed from 6.28 to 10.97% for damaged starch in wheat varieties (Table 2). Present findings are in good agreement with numerous investigations, which reported DS content in wheat flour varied as 6.07-12.81% (Mancebo *et al*., 2015; Farooq *et al*., 2001; Colombo *et al*., 2008). As, damaged starch has great ability to hold water and is highly hydrolyzed by ∝-amylase. It has been established that damaged starch increases water absorption to the level of 200-430% (Barrera *et al*., 2007). Water affects physio-chemical properties of wheat and degree of damaged starch significantly influence rheological and end product quality (El-Porai *et al*., 2013). Kang *et al*. (2014) found damaged starch varied from 2.08 to 7.90% in 30 Korean wheat cultivars. They further reported that it is directly influenced by kernel hardness, which in turn affected by genotype and environment.

SDS-sedimentation test. Table 2 lists mean values for SDS-sedimentation with varying levels from 18.20 to 30.50ml. It is reported that wheat varieties showed genetic variations with respect to SDS-sedimentation volume. This study accede with outcome of Naseem *et al*. (2011) as well as of Kumar *et al*. (2013) who measured SDS-sedimentation volume in wheat varieties in range of 23.83-33.02 ml. In work of Xiao *et al*. (2006) and in agreement with Kang *et al*. (2014), a wide range of SDS sedimentation values in wheat cultivars was found as 8.40-45.75 ml. Both high gluten level and quality leads to slower sedimentation (Hruskova and Famera, 2003). According to Shin *et al.* (2012), SDS-sed. volume was significantly affected by cultivar.

Alkaline water retention capacity. AWRC values showed variations over a wide range from 43.91 to 66.85% (Table 2). In present study, AWRC did change due to varietal differences. Outcome of this work endorse the findings of past authors who observed AWRC in wheat varieties ranged from 53.7 to 80.0% (Ram and Singh, 2004; Morris *et al.*,2004). According to Fustier *et al.* (2009a), the values of AWRC were determined aspatent (62.6%), middle-cut (64.2%) and clear fractions (71.1%), pointing out that peripheral layers of endosperm are more hydrophilic in nature.

Table 1. Chemical properties (%) of wheat varieties

Varieties	Moisture	Ash	Fat	Fiber	Protein	NFE	Wet gluten	Dry gluten
FSD-08	9.54±0.25^{ab}	0.63±0.017^{b}	1.34±0.035^{a}	0.47±0.012^{ab}	12.87±0.33^{b}	75.15±1.95^{a}	30.24±0.82^{ab}	9.08±0.25^{b}
Lasani-08	10.78±0.29^{a}	0.49±0.015^{c}	1.39±0.038^{a}	0.45±0.012^{b}	10.94±0.29^{c}	75.94±2.01^{a}	29.16±0.83^{d}	7.20±0.19^{c}
AARI-11	8.50±0.23^{b}	0.33±0.009^{d}	1.36±0.035^{a}	0.38±0.012^{c}	9.85±0.44^{d}	79.58±3.58^{a}	24.68±0.62^{bc}	7.12±0.20^{b}
T.D-1	10.58±0.30^{a}	0.83±0.017^{b}	1.49±0.043^{a}	0.52±0.012^{ab}	13.75±0.61^{a}	72.82±3.28^{a}	36.40±0.95^{c}	11.84±0.31^{c}
Benazir-13	9.76±0.28^{a}	0.66±0.023^{a}	1.46±0.040^{a}	0.51±0.017^{a}	13.13±0.37^{b}	74.48±2.10^{a}	33.92±0.88^{a}	9.80±0.25^{a}

Means sharing same letter in a column are statistically non-significant (P>0.05).

Table 2. SDS- sedimentation volume, AWRC and SRC values of wheat varieties

Varieties	DS (%)	SDS-sed. (ml)	AWRC(%)	WSRC(%)	SOCSRC(%)	SUCSRC(%)	LASRC(%)
FSD-08	8.43±0.32^{c}	25.40±0.92^{bc}	54.96±1.43^{b}	58.77±1.52^{b}	68.27±1.77^{b}	85.38±2.22^{bc}	80.44±2.09^{c}
Lasani-08	7.33±0.28^{d}	22.80±0.90^{a}	47.12±1.22^{a}	63.67±1.69^{ab}	68.20±1.81^{b}	81.99±2.18^{c}	95.48±2.53^{b}
AARI-11	6.28±0.23^{e}	18.20±0.77^{d}	43.91±1.19^{c}	50.83±1.38^{c}	56.66±1.54^{c}	75.79±2.06^{c}	79.43±2.15^{c}
T.D-1	10.97±0.48^{a}	30.50±1.02^{c}	66.85±1.70^{b}	66.38±1.88^{ab}	73.12±2.07^{b}	106.97±3.03^{a}	121.20±3.43^{a}
Benazir-13	10.38±0.38^{b}	29.20±0.97^{ab}	55.80±1.58^{c}	69.64±1.81^{a}	82.03±2.13^{a}	95.75±2.49^{ab}	116.91±3.04^{a}

Means sharing same letter in a column are statistically non-significant (P>0.05). SDS-sed= volume(SDS-sedimentation volume); AWRC= (Alkaline water retention capacity); WSRC= (Water solvent retention capacity); SOCSRC= (Sodium carbonate solvent retention capacity); SUCSRC= (Sucrose solvent retention capacity); LASRC= (Lactic acid solvent retention capacity).

Solvent retention capacity. SRC values varied greatly as 50.83-69.64, 56.66-82.03, 75.79-106.97 and 79.43-121.20% for WSRC, SOCSRC, SUCSRC and LASRC, respectively (Table 2). It is considered that variations in SRC values are likely due to genetic variations in wheat varieties. These observations were found to be in line with several articles (Švec *et al.*, 2012; Barrera *et al.*, 2007; Zhang *et al.*, 2007; Xiao *et al.*, 2006). Furthermore, Kang *et al.* (2014) stated that variations in SOCSRC, LASRC and WSRC values were generally accounted by cultivar (> 81%). According to Fustier *et al.* (2009b), SUCSRC that is related to pentosans and gliadin, revealed an upward trend from patent (72.6%) to clear flour (93.5%), might due to high levels of pentosan together with more protein as observed in clear flour.

Rheological properties. Statistical data presented in Table 3 divulged that rheological properties significantly (P<0.01) differed due to wheat varieties. Mean values varied over a wide range as 51.00-56.00% (water absorption), 1.20-4.20 min (dough development time), 2.90-18.20 min. (dough stability), 85.00-174.00 BU (degree of softening) and 48.00-200.00 (FQN). It is established that variations in rheological properties may possibly the consequence of differences in wheat varieties.It could be reasoned here that wheat varieties having lower rate of water absorption tended to be more suitable for cookie making and vice versa. Present study establish that wheat flour having high damaged starch also exhibited higher values of water absorption. Similar values were reported by various investigations related to farinographic studies (Naseem *et al*., 2011; Amjad *et al*., 2010). In addition, an increasein protein and damaged starch together with a reduced particle size of flour generally tend to heighten the water sorption of flour (Fustier *et al*., 2009a). However, Hadnadev *et al*. (2011) had agreed that dough development time depends on gluten quality, starch granules and level of DS.

Physical properties of cookies. Mean values (Table 4) indicated variations from 25.20 to 26.60 cm for width and from 5.80 to 6.40 cm for thickness of cookies prepared from wheat varieties. Spread factor of cookies varied significantly (P<0.01) from 39.38 to 45.86 and across varieties, AARI-11 yielded cookies with highest (45.86) spread factor. In view of Igrejas *et al*. (2002), the composition of flour protein have low impact on quality as compared to its level. In fact, higher levels of DS, arabinoxylan and protein exist in hard and durum wheat, all of which hold significant water content than soft wheat (Pauly *et al*., 2013). In this context, Pareyt *et al*. (2008) described that spread factor was found to decrease with increased protein and high gluten levels. Force required to break cookie prepared from wheat varieties ranged from 2.17 to 3.91 kg (Table 4). Variations in hardness of cookies might due to varietal differences of wheat. Present study report that higher values of

Table 3. Rheological properties of wheat varieties

Varieties	WA (%)	DDT (min)	DST (min)	DoS (BU)	FQN
FSD-08	55.00±1.44^{b}	3.20±0.15^{a}	10.90±0.29^{a}	122±3.17^{b}	181±4.79^{a}
Lasani-08	53.00±1.50^{ab}	2.50±0.06^{a}	4.20±0.12^{b}	135±3.76^{c}	184±5.21^{a}
AARI-11	51.00±1.39^{a}	1.20±0.06^{c}	2.90±0.06^{d}	174±4.91^{d}	200±5.20^{c}
T.D-1	56.00±1.50^{bc}	4.20±0.19^{d}	18.20±0.46^{d}	85±2.31^{a}	48±1.33^{a}
Benazir-13	54.20±1.39^{ab}	3.50±0.16^{b}	13.70±0.35^{c}	117±3.18^{bc}	109±2.83^{b}

Means sharing similar letter in a column are statistically non-significant (P>0.05).
WA(Water absorption); DDT(Dough development time); DST(Dough stability time); DoS(Degree of softening); FQN(Farinograph quality number)

Table 4. Physical and organoleptic properties of cookies prepared from wheat varieties

Varieties	Width (cm)	Thickness (cm)	Spread factor	Hardness (kg)	Overall acceptability
FSD-08	25.90±0.73^{ab}	6.10±0.23^{a}	42.40±0.51^{b}	3.45±0.16^{b}	7.25±0.32^{b}
Lasani-08	26.00±0.68^{a}	6.00±0.23^{a}	43.33±1.00^{ab}	2.95±0.15^{c}	7.50±0.36^{b}
AARI-11	26.60±0.72^{c}	5.80±0.06^{c}	45.86±1.24^{c}	2.17±0.13^{d}	7.75±0.36^{a}
T.D-1	25.20±0.65^{a}	6.40±0.06^{d}	39.38±1.06^{b}	3.91±0.18^{a}	6.75±0.25^{ab}
Benazir-13	25.50±0.68^{ab}	6.30±0.17^{b}	40.48±1.18^{b}	3.76±0.18^{a}	6.94±0.21^{a}

Means sharing similar letter in a column are statistically non-significant (P>0.05).

hardness in cookies from TD-1 and Benazir-13 (Sindh) wheat varieties may due to their water absorption capacities. Hardness is one of main property defining textural assessment of cookies and appraised as peak force to snap cookie and was found to be 40.21 N for wheat cookies (Manceboet *et al*., 2015). Overall acceptability scores of cookies prepared from wheat varieties (Table 4) were found to vary from 6.75 to 7.75. Panelists found cookies from AARI-11 had good color, surface appearance and highly acceptable as compared to other varieties. Low protein of AARI-11 may be one explanation for this attribute.

Correlation studies. All the parameters in present study were evaluated for their interdependence using Pearson's correlation coefficients (Table 5). In present study, correlation matrix revealed a significant and positive association of ash content with fibre (r= 0.954*) and hardness of cookies (r= 0.962**). While, a highly significant and negative correlation (r= -0.977**) between ash content of wheat flour and spread factor of cookies confirmed the importance of ash being indicative of cookie baking quality. Significant and positive associations of fiber content established with respect to protein (r= 0.935*), WSRC (r= 0.929*) and cookies hardness (r= 0.994**) are of statistical significance. Although, fiber content unveiled a highly significant but negative correlations with NFE content (r= -0.953*) and spread factor (r= -0.979**).

In present investigation, significant and positive association of protein was observed with damaged starch (r= 0.970*), DoS (r= 0.934*), SUCSRC (r= 0.919*) and hardness (r= 0.943*). While, protein indicated a highly significant negative (r= -0.968**) correlation with NFE and spread factor (r= -0.892*). The negative correlation between protein and spread factor corroborate the significant effect of protein content on spread factor. This may be explained by Chung *et al*. (2014), that larger cookies spread was reported with an increase in non-wheat protein level. In contrary, Moiraghi *et al.* (2013) reported that cookie factor had no relationship with protein.

In present work, it seems possible to inter-relate NFE with spread factor of cookies (r= 0.914*). Also, NFE revealed significant and negative correlation with damaged starch (r= -0.923*), degree of softening (r= -0.908*) and hardness (r= -0.949*).From correlation matrix, significant and positive relationships of damaged starch can be observed with degree of softening (r= 0.905*) and hardness (r= 0.905*). Figure 1 illustrates a highly significant and positive relationship between damaged starch and SUCSRC (r= 0.985**). The correlation between damaged starch and SUCSRC is well justified by Duyvejoncket *al*. (2011).

In present investigation, SOCSRC values correlated quite differently with cookie quality. From Table 5, it can be observed that SOCSRC had positive associations with WSRC (r= 0.952*) and hardness (r= 0.934*) while,

Table 5. Correlation matrix for different parameters of wheat varieties

	Ash	Fat	Fiber	Prot.	NFE	DS	WA	DoS	SDS	SOC	SUC	LA	WS	SF	H
Ash	1.00														
Fat	0.594	1.00													
Fiber	0.954*	0.724	1.00												
Prot.	0.834	0.671	0.935*	1.00											
NFE	-0.831	-0.687	-0.953*	-0.968**	1.00										
DS	0.812	0.842	0.917*	0.970**	-0.923*	1.00									
WA	0.618	0.450	0.755	0.883	-0.520	0.856	1.00								
DoS	0.636	0.636	0.782	0.934*	-0.908*	0.905*	0.273	1.00							
SDS	0.765	0.195	0.791	0.832	-0.529	0.822	0.912*	0.274	1.00						
SOC	0.968**	0.691	0.951*	0.780	-0.829	0.780	0.731	0.547	0.821	1.00					
SUC	0.740	0.890*	0.868	0.919*	-0.877	0.985**	0.858	0.882*	0.857	0.736	1.00				
LA	0.713	0.985**	0.818	0.730	-0.762	0.844	0.894	0.648	0.739	0.806	0.898*	1.00			
WS	0.864	0.783	0.929*	0.775	-0.874	0.784	0.541	0.627	0.729	0.952*	0.876	0.890	1.00		
SF	-0.977**	-0.578	-0.979**	-0.892*	0.914*	-0.838	-0.851	-0.693	-0.842	-0.952*	-0.758	-0.699	-0.892*	1.00	
H	0.962**	0.648	0.994**	0.943*	-0.949*	0.905*	0.749	0.775	0.556	0.934*	0.838	0.751	0.891*	-0.990**	1.00

* = Significant (P<0.05), * = Highly Significant (P<0.01). Prot = (Protein); NFE = (Nitrogen free extract); DS = (Damaged starch); WA = (Water absorption); DDT = (Dough development time); DoS = (Degree of softening); SOC = (Sodium carbonate); SUC = (Sucrose); LA = (Lactic acid); WS = (Water); T = (Thickness); SF = (Spread factor); H = (Hardness)

it was found negatively correlated to spread factor (r= -0.952*). Moreover, a significantly positive association can be determined between SUCSRC and degree of softening (r= 0.882*). Similarly, SUCSRC showed a significant and positive relation to LASRC (r= 0.898*). A significant and negative correlation was ascertained between WSRC values and spread factor (r= -0.892*). Present results are compatible to earlier researchers who observed that cookie factor was negatively associated with SOCSRC and WSRC as stated in earlier researchers (Colombo *et al*., 2008; Barrera *et al*., 2007). These results substantiate the negative effect of hydrophilic constituents on baking quality of cookies (Roccia *et al*., 2006).

Surprisingly, a positive correlation of water absorption with SDS sedimentation (r= 0.912*) was also found. This correlation underlines the importance of SDS sedimentation test to predict water absorption of wheat flour. However, in contrast to present results, Kaur *et al.* (2013) stated that water absorption was observed to be negatively associated with sedimentation volume (r= -0.437). Figure 2 represents a highly significant negative association between spread factor and hardness of cookies (r= -0.990**).

Conclusion

In present study, wheat varieties indicated significant variations in most of physico-chemical and sensory parameters. Of all wheat varieties, AARI-11 exhibited low damaged starch, water absorption and weak dough strength. Also, cookies produced from AARI-11 indicated highest spread factor. Here, we come to some general conclusions such as wheat variety; AARI-11 was remarkably well suited for cookie making on the basis of physico-chemical and sensory characteristics. Nonetheless, wheat varieties from Sindh were found unsuitable (being hard) for cookies and may have great potential for bread. In addition, cookies prepared from AARI-11 were evaluated best regarding surface appearance and overall acceptability. On the basis of correlation studies, it can be inferred that flour components had a strong impact on cookie quality.In addition, spread factor and hardness of cookies were influenced by WSRC and SOCSRC values. In present work, the correlations observed between water absorption and SDS-sed. volume as well as of damaged starch and SUCSRC values were of statistical significance. The authors deduced that appropriate use of these physico-chemical tests could help in the selection of specific varieties according to particular products.

Conflict of Interest. The authors declare no conflict of interest

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