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Relationship between wheat flour properties and french bread characteristics using principal component analysis

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ABSTRACT

The objective was to use Principal Component Analysis as a tool to assess the relationship between physical and rheological characteristics of wheat flour and the quality of french bread. Flours belonging to eight varieties of Argentine commercial wheats (*Triticum aestivum* L.) were studied. Physical and chemical determinations were performed on grains and then milled to obtain experimental flours. The rheological behaviour of flours was analysed through the alveographic and farinographic parameters and the technological characteristics through the French bread making. Principal component analysis was used as a statistical tool. The three principal components used can explain 78.4% of the variability of the original data extracted. Through the found results a certain association between alveographic and farinograph parameters was obtained, but were not found a close relationship between these physical properties with the specific volume of bread. So the PCA seem not to be an optimal tool to predict the quality of French bread from the properties of wheat flour. Nevertheless, the baking test appears as the more accurate tool to assess globally the parameters that determine the quality of flour.

KEYWORDS

Baking;
Wheat flour;
Principal component analysis,
French bread.

INTRODUCTION

Cereals are annual plants of high production. Cereal grains have low water content and this characteristic allows them long storage periods, with maintaining its nutritional value and germination power. They represent the biggest source of energy in the human diet[1].

Wheat (*Triticum aestivum* L.) is cropped in a wide region between 30-40° South Latitude and 57-68° West Longitude[2], which is divided into five sub-regions. The final use of wheat production will be set by the choice of genotypes. Wheat endosperm is classified into hard and soft. This classification is dependent of continuity of the protein matrix and the hardness affects the ease with which bran from the endosperm appears. Durum wheat endosperm cells are more cleanly separated and tend to remain intact. In soft wheat cells tend to fragment, releasing while another part is attached to the bran. Yields flour of soft wheat generally is smaller mean particle size and minor levels of damaged starch (and thus less water absorption) than hard wheat[3]. Flour quality depends of differences in kernel texture and, thus, the preferred use of any given flour. Soft wheat flour is used for cakes and cookies, hard wheat flour for bread and pasta[4].

Wheat flour characteristics are considerate to assess the quality of wheat because is the most important product. Rheological properties of dough are considered among the most important characteristics. The empirical rheological methods (alveograph, farinograph, amylograph) are widely used for its speed and simplicity to obtain information from the baking quality of dough obtained of wheat in evaluation. The flour quality is determined by evaluation the absorption of water, its physical properties and technological characteristics for the baking process[5].

Gluten is the main fraction that imparts functionality to wheat flour. Therefore it is considered that gluten content is an indicator of strength of the dough, provided by the amount and quality of protein[6]. During baking, the viscoelastic frame begins to be transformed in solid, being the gluten the main responsible in forming the structure that holds the gas. Mixing processes, fermentation, yeast concentration and moulded of dough affect the development of the gluten, thereby influencing the rheological properties of the dough[7].

As the consumers are becoming more sophisticated and the demand for healthy food is increasing, food texture is becoming a very important issue for food processors[8].

Bread flavour is the most important attribute for consumer acceptability[9]. The aromatic profile of breads contributes simultaneously to odour and flavour of breads, the term flavour covers the impressions perceived via the chemical senses from a product in the mouth. Defined in this manner, flavour also includes the olfactory perceptions caused by volatile substances perceived in the nasal cavity (retronasal route), the gustatory perceptions caused by soluble substances perceived as basic tastes in the mouth and chemical feeling factors (astringency, spice heat, cooling, bite) stimulating the nerve ends. Thus, flavour is the simultaneous perception of taste, odour and trigeminal nerve response[10]. Attributes or visual attributes includes attributes perceived by human sense of sight, such as crumb colour, crust colour or crumb structure[11]. An important part of bread texture is due to the quality of flour and dough used. Bread has a structure of more or less sensitive foam, surrounded by a rigid layer. Most of texture to be analyzed is made on the crumb and crust. The crust is crunchy when the bread is fresh[12]. French bread is the type of bread that better expresses differences between treatments, compared with bread made in moulds[13].

The fundamental basis of most modern methods for treatment of multivariate data is the PCA (Principal Component Analysis). It is a screening method that helps in the development of general hypotheses of the data collected, in contrast to studies that focused on hypotheses that were test before. This method projects the information in the original variables onto a small number of new variables, called principal components (PCs), which are linear combinations of the original variables. PCs are orthogonal to each other and give, in decreasing order, the best description of the variability in the data. This makes it possible to obtain an overview of the data, to find which properties are relate and which properties are most important to distinguish between samples[14]. Two variables that are close each other in the plot, represent the properties that vary in the same way, whereas variables appearing on the opposite sides are negatively correlated. The variables located in perpendicular directions along the axes of PC are independent of each other. PCA is possible to get a view of all data and find which properties are related and which are most important properties between samples. It is also able to separate important information from the redundant and random[15]. Osella *et al.* (2008)[16] applied PCA to determine factors which influence properties of dough and bakery products.

The objective of this work was to use PCA as a tool to assess the relationship between physical and rheological characteristics of wheat flour and the quality of French bread.

MATERIALS AND METHODS

Flour samples

Eight varieties of Argentine commercial wheats were evaluated through the following determinations: weight of thousand seeds[17] and test weight (PH)[18]. Samples were cleaned, then were moisturized at 15.5% and were stored for 24 hours before to be milled in a Buhler Miag mill type MLGV Variosthul and Buhler Rotostar Plansifter Type MPAR-H [16]. The following determinations were made: moisture[18], ash[17], wet gluten[18], alkaline water retention capacity (AWRC)[18] and physical dough properties. Water absorption (%), dough development time (min), degree of dough stability (BU) and degree of dough softening (BU) were measured with the Brabender farinograph on 300 g samples[18]. Deformation energy W (J x 10^{-4}), overpressure P (mm), swelling index G (ml), abscissa at rupture L (mm) and P/L ratio were measured with the Chopin alveograph on 250 g samples[18].

Baking test

Breads were made as a proposed baking test for French type bread[19]. The formula contained 300 g flour (14% moisture basis), 6 g yeast and 6 g NaCl was added with water according to farinograph water absorption to obtain equal dough consistency in all cases. Flour and yeast were mixed for one minute in the Brabender farinograph mixer with capacity of 300 g. Then the water was added at a temperature that would allow achieving a dough temperature of 24-26 °C. Kneading was done at 60 rpm for 15 min. After kneading, dough was rounded and fermented at 27 ºC and 80 % relative humidity, controlling the rising of volume with a push-meter, used to measure the dough leavened. In this instrument, 25 g of dough rises from 12 to 25 mm during 50-70 min. The apparatus consists of a glass cylinder (75 mm height, 45 mm i.d.) with a tight-fitting plastic piston that rises during proofing. After proofing, dough was divided into 100 and 200 g dough pieces, then shaped and proofed (final fermentation) at 27 ºC and 80 % relative humidity, controlling rising from 25 to 45 mm height with the push-meter. Pieces were baked at 210 ºC for 30 min using an electric oven with steam (Ojalvo S.A., Santa Fe, Argentina). Breads were evaluated after one hour to be baked. Loaf volume was determined by rapeseed displacement[19].

Statistical analysis

All the experiments were carried on in triplicate. Principal Component Analysis (PCA) was used to make statistical comparison and the analysis was done using statistical package Statgraphics 5.0 (Manugistics, Inc., Rockville, MD, USA).

RESULTS AND DISCUSSION

TABLE 1 shows results of weight of 1000 seeds and the test weight. In all cases, the milling yield was higher than 60 %.

TABLE 1 : Means of basics characteristics of wheat seeds

Varieties	1000 seeds weight (g)	Test weight (PH) (g/l)
1	34.5	78.43
2	41.4	86.34
3	41.5	82.98
4	41.0	84.84
5	32.9	83.84
6	41.8	81.72
7	37.4	77.53
8	40.4	83.18

The 1000 seeds weights were higher than the mean values expected of obtaining for each variety. This characteristic is important because was reported that kernel size correlated with flour milling yield when hard wheat cultivars were studied[20]. Bergman *et al.* (2000)[21] indicated that the lower the endosperm size, the higher the time of kernel grinding and the flour particle size. Drought often reduces the grain size and the milling yield and therefore is considered that reduces the grain quality[22]. Berman *et al.* (1996)[23] suggested that kernel traits could be used as a predictor of flour yield. Some authors reported that the test weight may be a good predictor of flour yield, while others suggested that this measurement may not be trusted for wheat predictions[24] but other method has not been found to replace the test weight.

TABLE 2 shows results of flour samples evaluation.

The found moisture values are adequate, thereby ensuring proper conservation from microbiological point of view. Also we can see that ash levels in

TABLE 2 : Chemical and physical characteristics of wheat flour

Varieties	Moisture (%)	Pelshenke assay	Ash (%)	Wet gluten (%)	Damage starch (%)	AWRC (%)
1	13.9	Soft	0.54	29.5	11.6	82.0
2	12.5	Strong	0.47	27.0	13.4	92.2
3	14.0	Soft	0.57	24.0	13.6	90.5
4	13.4	Strong	0.53	28.0	14.4	94.6
5	13.3	Strong	0.64	26.4	12.8	97.9
6	13.8	Strong	0.56	26.7	11.6	88.8
7	13.7	Strong	0.52	16.4	10.9	88.9
8	14.0	Strong	0.49	20.2	9.0	79.0

TABLE 3 : Means and ranges of wet gluten content and physical dough properties of flour samples

Variable	Mean	CV	Min	Max
Wet Gluten (%)	24.8	0.18	16.4	29.5
Farinograph data				
Water absorption (%) (14 % moisture basis)	63.1	0.05	58.6	67.4
Development time (min)	2	0.16	1.50	2.50
Stability (min)	2.2	1.12	1	11
Dough softening (B.U.)	79	0.40	12	130
Alveograph data				
P (mm)	133	0.16	106	157
P/L ratio	3.54	0.16	2.60	4.13
W ($Jx10^{-4}$)	257	0.21	176	345
Baking performance				
Specific volume (cc/g)	3.57	0.17	2.81	4.51

these flours are within the values of commercial flours, between 0.47 and 0.65 g of ash /100 g of flour. In the case of wet gluten, the variety numbered as 7 shows a very low value for having an adequate technological behavior. The damage starch values are higher (except sample 8) than the mean value of damaged starch of commercial flours[25]. Most of the results of AWRC were higher than those obtained by Barrera *et al.* (2007)[26]. We can appreciate that at high AWRC values also correspond high damaged starch values of the flour. This is important because those AWRC values are associated with the baking strength which means that damaged starch also improves the technological behavior at the same time that absorbs a higher quantity of water[27].

TABLE 3 shows wet gluten content and data of physical dough properties.

Dough softening and stability exhibit high coefficients of variation (CV) which is calculated as the rate of the standard deviation and the mean value, this indicates a large variation in quality among the varieties used in this study. The farinographic properties and the baking behaviour are generally affected by the level of damaged starch, because it influence the contribution of each protein to the gluten formation[28].

The mean value for wet gluten content was relatively low. Most of flours with low wet gluten, show low W values, and also low levels of development time and stability, and high values of dough softening, this means low quality of gluten for baking. In general, the use of this type of flours causes problems in making french type bread[29,16]. Therefore, flour from correctors wheat may be used for blending and improve their quality[30].

Specific volume of bread was ranged from 2.81 to 4.51 cc / g. These values were associated with P, L and P / L, and also with water absorption. These relationships are according to certain published data[31].

Figure 1 show PCA loadings for wet gluten, chemical and physical dough properties and French

TABLE 4 : Means and ranges of wet gluten content and physical dough properties of flour samples

Variable	Mean	CV	Min	Max
Wet Gluten (%)	24.8	0.18	16.4	29.5
Farinograph data				
Water absorption (%) (14 % moisture basis)	63.1	0.05	58.6	67.4
Development time (min)	2	0.16	1.50	2.50
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bread characteristics.

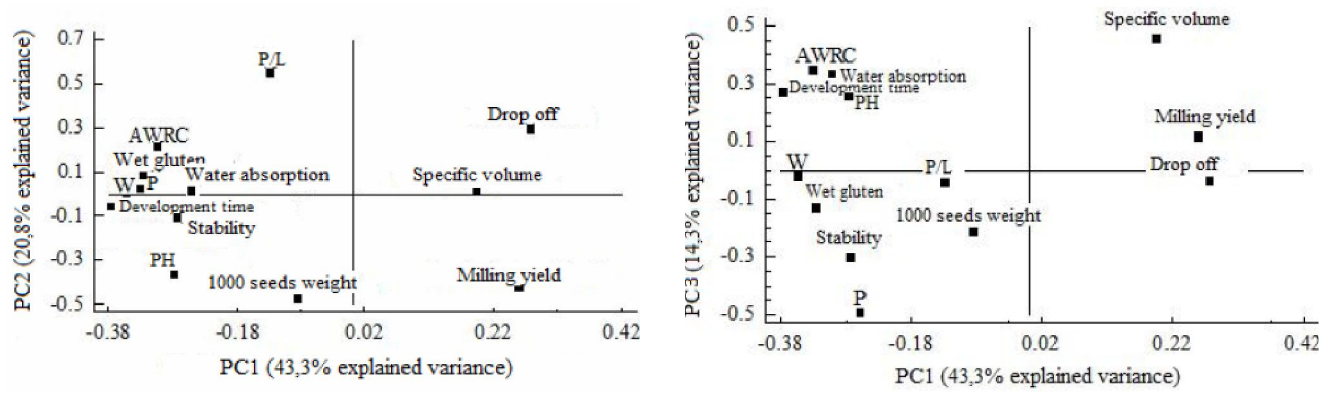
For data analysis, the three principal components which explain 78.4% of the variation of original data were extracted. This is explained by PC1 43.3%, PC2 20.8% and PC3 14.3%. In Figure 1(a), a close relationship between specific volumes, milling performance and the softening are detected along PC1. On the other hand a negative correlation between specific volume and wet gluten, development time and stability is detected. Steffolani *et al.* (2007)[32] and de la Horra *et al.* (2012)[33] found a strong association between the percentage of gluten and the protein content indicating that when the percentage of total protein increases, the gluten quantity also increases. But the amount of protein and gluten are not always directly related to the gluten quality. High content of protein or gluten, not necessarily indicates good behavior in baking force (W). According to Cuninberti *et al.* (2012)[34], protein and gluten can be estimated each other, but none of them showed a significant association with W and therefore, it could make mistake when are used as estimators industrial quality.

Nitrogen fertilization increases the percentage of protein and/or alter the proportions of Gliadin/Glutenin and the dough can register greater W. This increment in alveograph energy is due to the resulting increase in the extensibility of a higher content of gliadin[35], directly influencing industrial quality[36].

The technological quality of flours depends of the amino acid composition of gluten, specially of the presence of sulfur-containing amino acids, such as (-SH) thiol and disulfide groups (-SS)[37]. Along PC2, Figure 1 shows a close relationship between milling performance and the weight of thousand seeds and a smaller association with PH. In Figure 1(b), throughout the PC1, PH has a relationship with thousand seeds weight. Both parameters are shown by Hook (1984)[38] and Shuey (1960)[39] like predictors of wheat milling potential, being seed sizes better than the weight of them. In PC3 we can see the close relation between the specific volume, PH and AWRC. These PC3 shows that also exists a relationship between PH and milling yield, corroborated by authors cited previously, who established that the bigger the seed size the better the milling performance[40]. Confirmatory evidence of the reported correlations between seeds weight, milling yield and other end-use quality traits are needed prior that breeders and millers start using those measurements as predictors of any aspect of wheat quality[21].

CONCLUSIONS

There is an association between alveographic and farinograph parameters, but no close relationship between these physical dough characteristics with the specific volume. In the same way that Osella *et al.* (2006)[41] and Collado *et al.* (1996)[42], we can conclude that some rheological evaluations can predict certainly the technological behaviour of flour, like the relationships that have been shown



(a) (b)

Figure 1 : PCA loadings for wet gluten, chemical and physical dough properties and French bread characteristics. (a) PC1 and PC2 loadings; (b) PC1 and PC3 loadings

between specific volume, milling performance and drop off; or between milling performance, thousand seeds weight and the PH. Nevertheless, the baking test appears as a more accurate tool to assess globally the parameters that determine the quality of flour.

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