



Revista  
**Ciência, Tecnologia & Ambiente**

## A novel approach to classify refined wheat flour for use in pan bread

Uma nova abordagem para classificar farinha de trigo refinada para uso em pão de forma

Georgia Ane Raquel Sehn<sup>1\*</sup> , Caroline Joy Steel<sup>2</sup> 

<sup>1</sup> Departamento de Engenharia de Alimentos e Engenharia Química, Universidade do Estado de Santa Catarina – UDESC, Pinhalzinho, SC, Brasil. \*Corresponding author: georgia.sehn@udesc.br

<sup>2</sup> Departamento de Engenharia e Tecnologia de Alimentos, Faculdade de Engenharia de Alimentos, Universidade Estadual de Campinas – UNICAMP, Campinas, SP, Brasil.

**How to cite:** SEHN, G.A.R.; STEEL, C.J., 2026. A novel approach to classify refined wheat flour for use in pan bread. *Revista Ciência, Tecnologia e Ambiente*, vol. 16, e16313. <https://doi.org/10.4322/2359-6643.1613>.

### ABSTRACT

Technological and rheological properties of wheat flour, assessed via farinograph and extensograph analyses, critically determine dough behavior, enabling flour classification to predict pan bread quality. The aim of this study was to develop a dimensionless number able to predict the technological quality of pan bread made from refined wheat flours of the Brazilian market, through rheological analyses commonly performed to evaluate the quality of wheat flours. Two refined wheat flours (A and B) with different gluten strengths were used in different proportions for the preparation of premixes. According to the results from the rheological analyses, wheat flour A was considered suitable for the production of pan bread, with rheological characteristics from medium to strong, resulting in breads with specific volume of 4.15 mL g<sup>-1</sup>, while wheat flour B, with very strong characteristics, was unsuitable for pan bread making, resulting in breads with a specific volume of 3.41 mL g<sup>-1</sup>, probably due to its excessive resistance to extension (elasticity). By developing the dimensionless number of Sehn, it was possible to establish a classification for refined wheat flours as “suitable” (Sehn number between 1.30 and 2.60), and “unsuitable” (Sehn number below 1.30 or above 2.60) for the production of pan breads. In addition, an equation to predict the specific volume of pan breads made from refined wheat flour using the dimensionless number as the independent variable was developed.

**Keywords:** dimensionless number, extensograph, farinograph, specific volume.

### RESUMO

As propriedades tecnológicas e reológicas da farinha de trigo, avaliadas por meio de análises realizadas em farinógrafo e extensógrafo, determinam criticamente o comportamento da massa, permitindo a classificação das farinhas para prever a qualidade final de pães de forma. O objetivo deste estudo foi desenvolver um número adimensional capaz de prever a qualidade tecnológica do pão de forma produzido a partir de farinhas de trigo refinadas do mercado brasileiro, utilizando análises reológicas comumente realizadas para avaliar a qualidade das farinhas de trigo. Duas farinhas de trigo refinadas (A e B), com diferentes forças de glúten, foram utilizadas em proporções distintas na preparação de pré-misturas. De acordo com os resultados das análises reológicas, a farinha A foi considerada adequada para a produção de pão de forma, apresentando características reológicas de médias a fortes, resultando em pães com volume específico de 4,15 mL g<sup>-1</sup>, enquanto a farinha B, com características muito fortes, foi inadequada para a panificação, resultando em pães com volume específico de 3,41 mL g<sup>-1</sup>, provavelmente devido à sua resistência excessiva à extensão (elasticidade). Ao desenvolver o número adimensional Sehn, foi possível estabelecer uma classificação para as farinhas de trigo refinadas como “adequadas” (número de Sehn entre 1,30 e 2,60) e “inadequadas” (número de Sehn inferior a 1,30 ou superior a 2,60) para a produção de pão de forma. Além disso, foi desenvolvida uma equação para prever o volume específico do pão de forma produzido a partir de farinha de trigo refinada, utilizando o número adimensional como variável independente.

**Palavras-chave:** número adimensional, extensógrafo, farinógrafo, volume específico.



## INTRODUCTION

All wheat flour-based products (bread, pasta, cakes, and biscuits) require flours with specific technological characteristics, and the choice of flour is a key factor to formulate an acceptable product. Wheat flour characteristics are related to gluten forming proteins (gliadins and glutenins) that form a viscoelastic network during mixing and development of dough (Hoseney, 1998; Bamyar et al., 2025).

Rheological tests with wheat flour assist industries in predicting the processing characteristics and quality of the final product, being part of a set of procedures, including bread quality tests (Rao and Rao, 1991; Aljahani, 2022). Within the industry (mills and large bakery industries), various instruments are used to measure the rheological properties of dough, and the farinograph and extensograph are widely used for providing useful data to evaluate the performance during processing and quality control (Zhao et al., 2025).

The farinograph is used to evaluate the mechanical behavior of wheat doughs, reproducing process conditions during the mixing step. According to Preston and Kilborn (1984), by farinograph analysis, wheat flour can be classified as weak, medium, strong, and very strong. Weak flours have water absorption (WA) lower than 55%, dough development time (DDT) lower than 2.5 min, stability (S) lower than 3 min, and mixing tolerance index (MTI) over 100 BU (Brabender Units). Strong flours have WA higher than 58%, DDT from 4 to 8 min, S from 8 to 15 min, and MTI from 15 to 50 BU. Medium flours are those with intermediate values between weak and strong flours. The flours with DDT over 10 min, S higher than 15 min, and MTI lower than 10 BU have very strong dough characteristics. For good results, strong flours are used for bread making, medium flours for the production of crackers, and weak flours for manufacturing biscuits and cakes. According to Mailhot and Patton (1988), flours used in breadmaking must have the following characteristics: medium to high water absorption (59 to 65%), dough development time of 5 to 8 min, and minimum stability of 7.5 min. According to the Brazilian legislation, flour suitable for bread making must have a minimum stability of 10 min (Brasil, 2010).

The extensograph was introduced to supplement information provided by the farinograph, being used to evaluate wheat flour dough behavior during fermentation and resting. Dough is evaluated at three rest periods (45, 90, and 135 min) to assess the evolution of dough characteristics (elasticity and extensibility) over time. A decrease in resistance with time means that the flour has a reduced ability to retain gas during fermentation (Pizzinatto, 1997). It is reported that maximum resistance and the area under the curve can be used as indicators of dough strength (Preston and Hoseney, 1991). According to Mailhot and Patton (1988), wheat flour used in bread making must have a balance between the characteristics of extensibility (E) and resistance to extension (R). As reported by Pizzinatto (1997), flour can be classified as weak and strong, with resistance to extension and extensibility of 130 BU and 180 mm, and 560 BU and 155 mm, respectively.

Brazil produces approximately half of the wheat it consumes and imports the remainder from countries such as Argentina and the United States. This wheat is blended and milled into wheat flour in mills distributed throughout the country (Associação Brasileira da Indústria do Trigo, 2025). However, not all bakery industries that receive this raw material from mills have adequate instruments to assess the rheological properties of these flours and, consequently, to define their appropriate applications. Developing a simple method of classification can help smaller industries to destine determined wheat flours or mixtures thereof for the manufacture of high-quality pan bread (higher specific volume) only with the results obtained in reports issued by wheat flour mills.

This simple method could involve the development of a dimensionless number using results from farinograph and extensograph analyses, as already done in our previous study (Sehn and Steel, 2017) for whole wheat flour. Dimensionless numbers are used to plan and correlate experimental research projects or to interpret results of experiments. Through these numbers it is possible to group variables, in dimensionless terms, expressing certain ratios (Foust et al., 1982).

In previous study (Sehn and Steel, 2017), was developed a dimensionless number (Sehn-Steel number), using the results from farinograph and extensograph

analyses, to determine the suitability of whole wheat flours to produce pan bread. Samples used to generate the data were prepared with different percentages of wheat bran. However, it is known that refined and whole wheat flours behave quite differently when submitted to rheological analyses, based on consistency measurements, as dough consistency derives from different components in the wheat. In whole wheat flours, dough consistency is determined both by protein quality and by the fibers present in greater quantity in the bran. In refined flours, dough consistency is given mainly by protein quality, and the ability of gluten proteins to form a weaker or stronger network. Therefore, dimensionless numbers based on rheological analyses of whole and refined wheat flours need to be evaluated in different ways.

Based on this, the aim of this study was to develop a dimensionless number able to predict the technological quality of pan bread made from refined wheat flours with different gluten quality, using the results of rheological analyses commonly supplied by wheat flour mills.

## MATERIAL AND METHODS

### Material

The refined wheat flours used in this study were: Flour A (Moinho Ipiranga, Santa Maria, BRA) and Flour B (Moinho Anaconda, São Paulo, BRA).

### Methods

#### Characterization of raw material

Wheat flours were characterized for chemical composition using the following determinations, performed in triplicate: moisture, protein (conversion factor 5.7), fat, and ash contents according to AACC methods 44-15.02, 46-13.01, 30-25.00, and 08-01.01,

respectively (American Association of Cereal Chemists, 2010); Falling Number according to AACC method 56-81.03; and total dietary fiber content according to AOAC method 985.29 (Association of Official Analytical Chemists, 2000).

#### Rheological characterization of refined wheat flour premixes

Refined wheat flour (A) was mixed with refined wheat flour (B) in proportions of 0:100; 16.7:83.3; 33.3:66.7; 50:50; 66.7:33.3; 83.3:16.7 and 100:0%, generating 7 premixes. The premixes were prepared in 4 kg batches using a V-blender (Tecnal, Piracicaba, Brazil) for 20 min.

The premixes were characterized for farinograph parameters (water absorption, dough development time, stability, and mixing tolerance index) according to the method 54-21.02 of the American Association of Cereal Chemists (2010) using a farinograph model 827505 (Brabender, Duisburg, DEU), and extensograph parameters (resistance to extension and extensibility) according to the method 54-10.01 of the American Association of Cereal Chemists (2010) in an extensograph model 860703 (Brabender, Duisburg, DEU). All determinations were performed in triplicate.

#### Manufacture of pan breads

Pan breads were prepared in duplicate from the 7 premixes, using the same formulation, following the procedure described by Schmiele et al. (2012), with modifications (flour basis): premix (100%); sucrose (4%); sodium chloride (1.8%); instant dry yeast (2%); whole milk powder (4%); vegetable fat (4%); calcium propionate (0.6%), and fungal alpha-amylase (0.0025%). The amount of water was based on the water absorption of the different premixes assessed by the farinograph analysis (Table 1).

**Table 1.** Rheological properties and dimensionless numbers for the different flour pre-mixes A and B.

PM	A:B (%)	WA (%)	S (min)	DDT (min)	MTI (UB)	E45 (mm)	E135 (mm)	R45 (UB)	R135 (UB)	SV (mL/g)	Sehn
1	100:0	56.4	14.60±0.10 <sup>c</sup>	10.17±0.29 <sup>c</sup>	35.00±3.46 <sup>a</sup>	143.00±4.32 <sup>a</sup>	104.40±6.42 <sup>a</sup>	277.00±18.73 <sup>d</sup>	597.00±23.52 <sup>d</sup>	4.15±0.02 <sup>a</sup>	1.974
2	83.3:16.7	56.5	15.27±0.50 <sup>bc</sup>	10.17±0.06 <sup>c</sup>	37.67±4.51 <sup>a</sup>	123.07±1.96 <sup>bcd</sup>	82.87±4.08 <sup>bcd</sup>	311.67±29.48 <sup>d</sup>	708.67±41.79 <sup>cd</sup>	3.99±0.01 <sup>b</sup>	1.304
3	66.7:33.3	56.7	16.97±0.50 <sup>cd</sup>	11.30±0.46 <sup>bc</sup>	32.33±2.08 <sup>ab</sup>	127.07±3.99 <sup>bc</sup>	96.10±7.07 <sup>ab</sup>	391.33±17.04 <sup>c</sup>	763.3±63.69 <sup>bc</sup>	4.19±0.08 <sup>a</sup>	1.734
4	50:50	56.6	17.83±0.35 <sup>c</sup>	12.07±0.93 <sup>b</sup>	28.67±1.15 <sup>b</sup>	121.97±1.76 <sup>bcd</sup>	93.93±7.17 <sup>abc</sup>	454.00±34.39 <sup>bc</sup>	857.33±49.22 <sup>b</sup>	3.87±0.01 <sup>c</sup>	2.115
5	33.3:66.7	58.3	19.80±0.70 <sup>b</sup>	14.30±0.36 <sup>a</sup>	31.33±1.53 <sup>ab</sup>	118.87±2.31 <sup>cd</sup>	82.60±6.41 <sup>bcd</sup>	521.00±13.75 <sup>ab</sup>	1043.67±2.08 <sup>a</sup>	3.96±0.07 <sup>bc</sup>	1.525
6	16.7:83.3	58.8	21.23±0.91 <sup>ab</sup>	15.10±0.26 <sup>a</sup>	36.67±4.73 <sup>ab</sup>	118.60±3.31 <sup>d</sup>	77.83±4.72 <sup>cd</sup>	513.00±48.87 <sup>ab</sup>	1083.33±61.86 <sup>a</sup>	3.91±0.08 <sup>bc</sup>	1.051
7	0:100	59.3	23.10±1.11 <sup>a</sup>	15.13±0.81 <sup>a</sup>	30.67±2.89 <sup>ab</sup>	127.83±2.54 <sup>b</sup>	70.33±3.67 <sup>d</sup>	535.00±14.00 <sup>a</sup>	1147.33±51.54 <sup>a</sup>	3.41±0.03 <sup>d</sup>	0.466

Mean ± standard deviation; PM: pre mixes; WA: water absorption; S: stability; DDT: dough development time; MTI: mixing tolerance index; E45: extensibility at 45 minutes; E135: extensibility at 135 minutes; R45: resistance at 45 minutes; R135: resistance at 135 minutes; UB: Brabender Units; SV: specific volume; Sehn: dimensionless number (calculated according to Equation 1). Different lowercase letters in the same column indicate significant differences between the samples by Tukey test ( $p \leq 0.05$ ).

The ingredients were mixed in an automatic mixer (Hypolito, Ferraz de Vasconcelos, BRA) at low speed (~90 rpm) for 5 minutes, and at high speed (~210 rpm) until complete development of the gluten network. Dough was divided in portions of  $450 \pm 1$  g, modeled in a molder, model MPS 350 (GPaniz, Caxias do Sul, BRA), placed in open pans (dimensions 20 cm x 10 cm x 5 cm) and taken to a fermentation chamber, model 20-1 (Super Freezer, Poços de Caldas, BRA), at 30 °C and 80% RH, for 100 minutes.

Breads were baked in an electric oven, model IP 4/80 (Haas, Curitiba, BRA), adjusted to temperatures of 170 °C (top) and 185 °C (hearth) for 30 minutes. After baking, the breads were cooled for 3 hours at room temperature and removed from the pans. Then, the specific volume was determined in triplicate by the method 10-05.01 of the American Association of Cereal Chemists (2010).

#### Statistical Analysis

The chemical composition of refined wheat flours A and B was evaluated using Student's t-test ( $p \leq 0.05$ ). Rheological properties and specific volume of premixes and bread were analyzed by analysis of variance (ANOVA), followed by Tukey's test to determine significant differences among means ( $p \leq 0.05$ ), using Statistica 10.0 software (StatSoft Inc., Tulsa, OK, USA).

The rheological parameters of wheat flour and the specific volume of pan breads were analyzed by linear regression (least squares method) for setting simple and quadratic linear functions, using the software Statistica (Trial) (STATSOFT, Tulsa, USA).

The development of the dimensionless number of Sehn involved calculations for the selection

of farinograph and extensograph parameters of wheat flour, by applying the method of maximum likelihood estimation to determine the exponents of the dimensionless function of Sehn. The method of maximum likelihood estimation adjusts the best function  $f(x)$  to a set of data points (Vuolo, 1996). In the specific case of adjusting the function to a set of data points, the maximum likelihood estimation can be defined as the best function  $f(x)$  to describe a set of data points, which is most likely when the function  $f(x)$  is accepted as the true function.

## RESULTS AND DISCUSSION

### Characterization of Raw Material

Table 2 shows the values of chemical composition and Falling Number of wheat flours A and B, which presented protein contents of 11.07% and 10.39%, respectively. According to Mailhot and Patton (1988), protein levels suitable for the production of pan breads may vary from 11 to 13%, and lower amounts may result in lower specific volumes. Although flour A showed higher lipids and lower ash content when compared to flour B, both flours did not differ in total dietary fiber levels.

The Falling Number is an estimate of  $\alpha$ -amylase content in wheat flour. It is known that this enzyme degrades starch to dextrins and oligosaccharides, facilitating the action of  $\beta$ -amylase. In the present study, flour A and B exhibited Falling Number values of 597 and 515 seconds, respectively. Flours suitable for bread making must have Falling Number between 200 and 300 seconds (Mailhot and Patton, 1988), thus the use of the enzyme as a processing aid was necessary for the production of pan breads in this study.

**Table 2.** Characterization of refined wheat flour A and B.

Analysis	A	B
Moisture (%)	11.82±0.43 <sup>b</sup>	13.26 ± 0.03 <sup>a</sup>
Protein (%) <sup>*</sup>	11.07±0.12 <sup>a</sup>	10.39 ± 0.81 <sup>a</sup>
Lipid (%) <sup>*</sup>	1.20±0.26 <sup>a</sup>	0.53 ± <0.01 <sup>b</sup>
Ash (%) <sup>*</sup>	0.57±0.03 <sup>b</sup>	1.18 ± 0.10 <sup>a</sup>
Total Dietary Fiber <sup>†</sup>	3.43±0.29 <sup>a</sup>	3.69 ± 0.28 <sup>a</sup>
Total Carbohydrates (calculated by difference) <sup>*</sup>	87.2	87.9
Falling Number (s)	597±26 <sup>a</sup>	515±25 <sup>b</sup>

Mean ± standard deviation. <sup>\*</sup>Values on a dry basis. <sup>†</sup>fraction included in carbohydrates. Different small letters in the same line indicate significant difference between samples by Student's t-test ( $p \leq 0.05$ ).

### Rheological Analysis of Wheat Flour Premixes and Specific Volume of Pan Breads

Table 1 shows the results of farinograph and extensograph analysis of refined wheat flour premixes used to calculate the dimensionless number, as well as the specific volume of the pan breads produced with them.

Water absorption determined by the farinograph analysis corresponds to the amount of water added to the flour (14% moisture) to form dough with consistency of 500 BU (considered optimal for bread making). Higher water absorption values were observed with higher amounts of flour B. According to Tipples et al. (1978), the protein and damaged starch contents in wheat flour have a positive impact on water absorption. The flours used in this study were not significantly different with respect to protein content. Possibly, the greater water absorption observed for flour B was inherent to higher damaged starch content, or due to a higher content of pentosans, which are major non-starch polysaccharides that compete with gluten for water absorption (Zhang et al., 2025). According to Preston and Kilborn (1984), strong flours tend to absorb greater amounts of water (above 58%), suggesting that flour B has greater gluten strength than flour A.

Dough development time (DDT) is the time in minutes necessary for dough to reach its maximum consistency. All flours of the present study showed two peaks. According to AACC International guidelines (American Association of Cereal Chemists, 2010), in this case, the second peak should be considered as DDT. Dough stability (S) indicates the tolerance of the dough to mixing, or the period in which the farinograph curve remains on the 500 BU line, when hydration of the flour components and development of the gluten network are observed. An increase in dough development time and stability was observed with greater amounts of flour B, which was expected, due to the higher DDT and S of this flour (15.1, and 23.1 min, respectively).

The mixing tolerance index (MTI) indicates tolerance to over-mixing (showing the loss in consistency of the dough after optimal development), and is determined by the difference between the top of the curve at the peak (greatest consistency) and the top of the curve measured 5 minutes after the peak is reached, in BU. No significant difference was observed for the flours under study

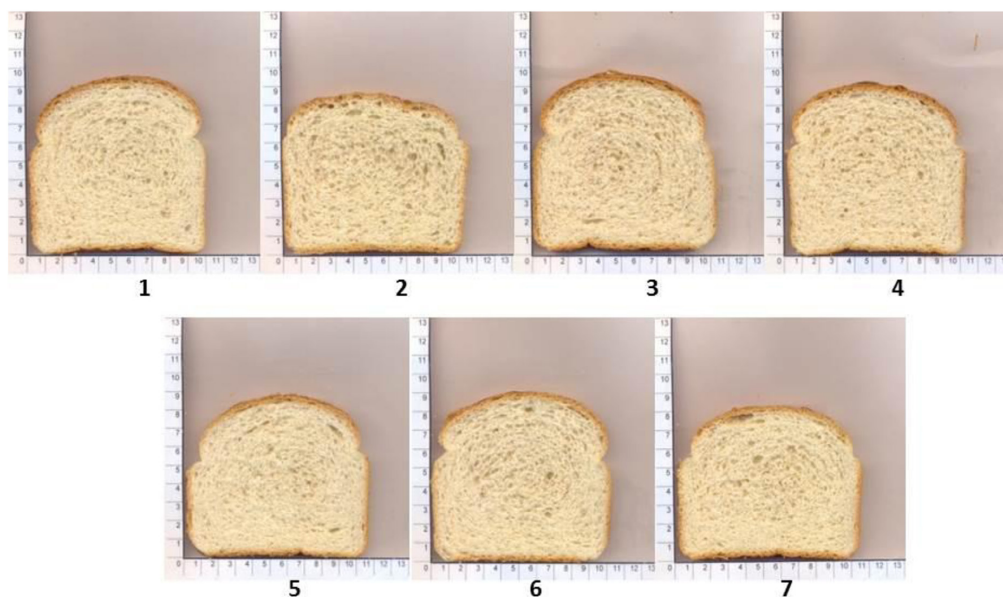
(A and B) for this parameter, and the minimum value (28.7 BU) was found when a balance of the two flours was used (50% A and 50% B), which was significantly different from the sample containing 83.3:16.7 (A:B), that presented higher MTI (37.7 BU).

The parameters resistance to extension (R) and extensibility (E) were evaluated in the extensograph, and corresponded to the height in BU measured in the extensogram, at 50 mm extension, and to the distance the dough stretches before breaking, respectively. These tests are performed after three resting periods (45, 90, and 135 min), which according to Catterall and Cauvain (2009) are the periods during which a dough is fermented, being the first stretching at 45 min the most relevant.

Flour B had a higher resistance to extension, at 45 min (535.0 BU), and 135 min (1147.3 BU), and lower extensibility (127.8 mm and 70.3 mm, at 45 and 135 min, respectively), when compared to flour A. In accordance with the rheological measurements and standards described by Preston and Kilborn (1984), wheat flour A was considered a medium to strong flour, while flour B had strong flour characteristics.

Specific volume is one of the most important measurements made in bread to evaluate flour quality (Mondal and Datta, 2008). Flours with the same protein contents may have different quality (strength), directly influencing the specific volume. Breads made from flour A, which had medium to strong characteristics, thus considered suitable for bread making according to Mailhot and Patton (1988), had higher specific volume (4.15 mL g<sup>-1</sup>). A similar trend was also found for the formulation with 66.67:33.3 (A: B) (4.19 mL g<sup>-1</sup>). In contrast, a lower specific volume (3.41 mL g<sup>-1</sup>) was observed for the breads made from 100% flour B, considered very strong, thus inadequate for bread making. This may be due to its high resistance to extension (elasticity), which prevented dough expansion during the fermentation and baking steps. Figure 1 shows images of the central slices of breads produced with the 7 premixes.

A wide range of specific volumes of pan bread made from refined wheat flour is found in the literature: 3.5 mL g<sup>-1</sup> (Irakli et al., 2015), 3.75 mL g<sup>-1</sup> (Tuncel et al., 2014), 4.01 mL g<sup>-1</sup> (Conto et al., 2012), 4.36 mL g<sup>-1</sup> (Schmiele et al., 2012), and 5.28 mL g<sup>-1</sup> (Aljahani, 2022).



**Figure 1.** Center slice of breads made with premixes of refined wheat flour A:B (100:0; 83.3:16.7; 66.7:33.3; 50:50; 33.3:66.7; 16.7:83.3; 0:100, for formulations 1 to 7, respectively).

This variation is inherent both to the type of flour and to formulation factors, including the level and type of improvers, enzymes, emulsifiers, and other processing aids, in addition to differences in processing conditions.

Considering this broad interval, the value of  $4.00 \text{ mL g}^{-1}$  was adopted as a representative intermediate reference within the range commonly reported for refined wheat flour breads. This value approximates the central tendency of the literature data and represents a technologically acceptable specific volume under conventional baking conditions. Therefore,  $4.00 \text{ mL g}^{-1}$  was established as the reference threshold for classifying flours as suitable or unsuitable for producing pan bread under the experimental conditions adopted in this study.

#### Sehn Dimensionless Number

Dimensionless numbers consist of numbers devoid of any physical unit, obtained by dividing the equation by one of the terms, in which each product or quotient indicates in dimensionless form the ratio of the mechanism contributions in the numerator and denominator. The dimensionless analysis reduces the number of variables to be considered in experimental models or correlation data (Foust et al., 1982).

The farinograph variables used to define the dimensionless number, called the dimensionless number of Sehn, were water absorption, dough development time, stability, and mixing tolerance index, while the

extensograph variables were extensibility and resistance to extension at 45 and 135 min. The intermediate time of 90 min was not used, since the difference between the maximum and minimum values of the dimensionless number at 135 and 45 minutes was greater than the difference using the maximum and minimum values of the dimensionless number calculated at 90 and 45 minutes.

To define the dimensionless number of Sehn, calculations for the selection of rheological results of the refined wheat flour were performed, by applying the maximum likelihood method to determine the values of the function exponents, according to Equation 1.

$$SEHN = (WA - 14)^{-4} \times \left[ \frac{S(\text{min})}{DDT(\text{min})} \right]^{-3} \times \left[ \frac{500(BU)}{MTI(BU)} \right] \times \left[ \frac{R135(BU)}{R45(BU)} \right]^{-4} \times \left[ \frac{E135(BU)}{E45(BU)} \right]^2 \times 10^6 \quad (1)$$

where: WA= water absorption of flour ( $\text{g } 100\text{g}^{-1}$ ); S = flour stability (minutes); DDT = dough development time (minutes); 500 = reference of dough resistance at 500 BU; MTI= mixing tolerance index (BU); E45 = extensibility at 45 minutes (mm); E135 = extensibility at 135 minutes (mm); R45 = resistance to extension or elasticity at 45 minutes (BU); R135 = resistance to extension or elasticity at 135 minutes (BU).

Table 1 shows the dimensionless number of Sehn of the 7 premixes used in this study, calculated according to Equation 1. Figure 2 shows the results of the specific volume as a function of the dimensionless number of Sehn.

The proposed classification of refined flour (Table 3) used the dimensionless number of Sehn, calculated according to Equation 1. Two classes were determined using only the specific volume of  $4.0 \text{ mL g}^{-1}$  as quality parameter. Thus, unsuitable flours were those producing breads with specific volumes lower than  $4.0 \text{ mL g}^{-1}$  and a dimensionless number of Sehn lower than 1.30 or greater than 2.60. Flours producing breads with specific volumes higher than or equal to  $4.0 \text{ mL g}^{-1}$  and a dimensionless number greater than or equal to 1.30 and lower than or equal to 2.60 were considered suitable for bread making. With this classification, through the results of analyses normally used in the bakery industry, it is possible to predict whether a determined wheat flour can be used to make high quality pan bread. Even smaller bakeries, that do not have farinograph and extensograph equipment at their disposal, but have these results in reports issued by wheat flour mills, will be able to use this tool to obtain pan bread with high specific volume.

#### Analysis of Variance of Quadratic Fitting and Statistical Model of the Specific Volume as a Function of the Dimensionless Number of Sehn

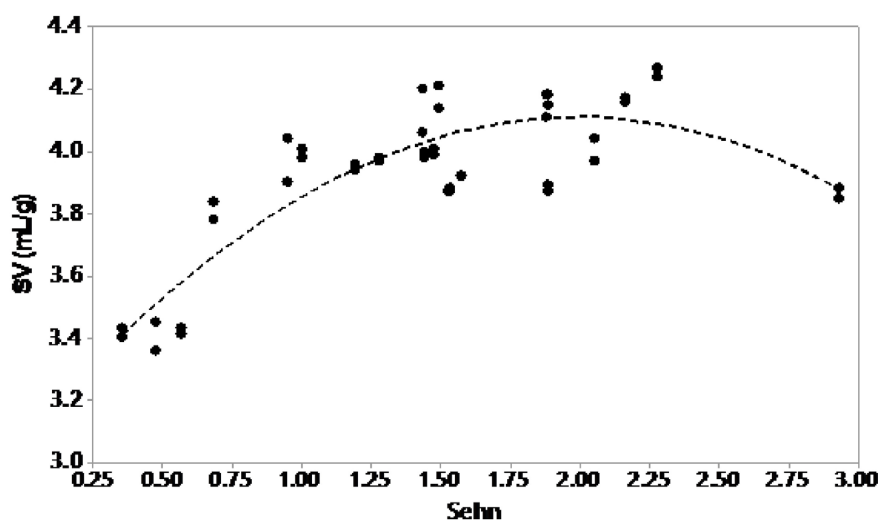
For the analysis of variance of the relationship between specific volume and the Sehn dimensionless number, the probability of significance found was of 0.00003 ( $p \leq 0.05$ ), confirming that the quadratic regression model was statistically significant. The proportion of explained variance ( $R^2$ ) found was of 0.75.

A statistical model was obtained to estimate the specific volume (Equation 2), consisting of a prediction of the specific volume of pan bread made from refined wheat flour, taking into account the dimensionless number of Sehn.

$$SV \left( \frac{\text{mL}}{\text{g}} \right) = -0,2623 \times \text{Sehn}^2 + 1,0435 \times \text{Sehn} + 3,0699 + e \quad (2)$$

where: SV: specific volume; Sehn: dimensionless number calculated according to Equation 1; e: experimental error.

The parameters for calculating the dimensionless number of Sehn require the results of the rheological analyses (farinograph and extensograph), thus providing the specific volume of breads. Two wheat flours with different gluten strength (A and B) were prepared at different ratios and used as basis.



**Figure 2.** Relationship between the Sehn dimensionless number (calculated according to Equation 1) and the specific volume of pan breads. Each point represents one flour sample evaluated.

**Table 3.** Classification of refined flours for the production of pan breads.

Sehn	Wheat flour	SV (mL/g)
Sehn < 1.30	Unsuitable	Less than 4.0
$1.30 \leq \text{Sehn} \leq 2.60$	Suitable	Approximately or more than 4.0
Sehn > 2.60	Unsuitable	Less than 4.0

SV: Specific volume; Sehn: dimensionless number (calculated according to Equation 1).

A study of refined wheat flour with weak characteristics, i.e., lower technological quality for bread making (used in the production of cakes and biscuits) can increase the range of rheological results, allowing the classification of flours for different applications, and sorting the flours that are suitable and unsuitable for the production of pan bread.

## CONCLUSION

This study showed that it was possible to develop the dimensionless number of *Sehn*, which allowed establishing a classification of refined wheat flour as suitable and unsuitable for the production of pan bread using only the specific volume as a quality criterion of the final product. Thus, wheat flours with a dimensionless number of *Sehn* lower than 1.30 or greater than 2.60 was considered unsuitable for the production of pan bread, while those with a dimensionless number between 1.30 and 2.60 were suitable for the production of pan bread. In addition, an equation to predict the specific volume of breads made from refined wheat flour was developed as a function of the dimensionless number of *Sehn*. With this classification, through the results of analyses normally used in the bakery industry, it is possible to predict whether wheat flour can be used to make high quality pan bread.

## ACKNOWLEDGMENTS

We would like to thank Ipiranga Wheat Mill and Anaconda Wheat Mill for the donation of the wheat flours used in this study. Also, author G.A.R.S. is grateful to CNPq for her PhD scholarship (Process number 140615/2012-1) and author C.J.S. is grateful to CNPq for her Productivity Grant (Process number 311185/2022-3). Both authors acknowledge the project funding from FAPESP (Process number 2013/08538-0).

## REFERENCES

ALJAHANI, A.H., 2022. Wheat-yellow pumpkin composite flour: physico-functional, rheological, antioxidant potential and quality properties of pan and flat bread. *Saudi Journal of Biological Sciences*, vol. 29, no. 5, pp. 3432-3439. <https://doi.org/10.1016/j.sjbs.2022.02.040>. PMID:35844428.

AMERICAN ASSOCIATION OF CEREAL CHEMISTS – AACC, 2010. *Approved methods of analysis*. 11th ed. St. Paul: AACC International.

ASSOCIAÇÃO BRASILEIRA DA INDÚSTRIA DO TRIGO – ABITRIGO, 2025 [viewed 20 September 2025]. *Estatísticas* [online]. Available from: <http://www.abitrigo.com.br/categoria-estatisticas/farinha-de-trigo/>

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS – AOAC, 2000. *Official methods of analysis of Association of Official Analytical Chemists*. 17th ed. Gaithersburg: AOAC.

BAMYAR, E., PEIGHAMBARDoust, S.H. & GHAZIANI, M.A., 2025. Bridging agriculture and food: Aqueous ozone treatment optimizes wheat flour characteristics and dough rheology to enhance bread quality in Iranian cultivars. *Journal of Agriculture and Food Research*, vol. 22, pp. 102036. <https://doi.org/10.1016/j.jafr.2025.102036>.

BRASIL. Ministério da Agricultura, Pecuária e Abastecimento, 2010 [viewed 5 September 2025]. Instrução normativa nº 38, de 30 de novembro de 2010. Regulamento Técnico do trigo. *Diário Oficial da República Federativa do Brasil* [online], Brasília. Available from: <http://sistemasweb.agricultura.gov.br/sislegis/action/detalhaAto.do?method=visualizarAtoPortalMapa&chave=358389789>

CATTERALL, P. & CAUVAIN, S.P., 2009. Moagem da farinha. In: S.P. CAUVAIN & L.S. YOUNG, eds. *Tecnologia da panificação*. Barueri: Manole, pp. 349-388.

CONTO, L.C., OLIVEIRA, R.S.P., PEREIRA MARTIN, L.G., CHANG, Y.K. & STEEL, C.J., 2012. Effects of the addition of microencapsulated Omega-3 and rosemary extract on the technological and sensory quality of white pan bread. *Lebensmittel-Wissenschaft + Technologie*, vol. 45, no. 1, pp. 103-109. <https://doi.org/10.1016/j.lwt.2011.07.027>.

ESTELLER, M.S. & LANNES, S.C.S., 2005. Parâmetros complementares para fixação de identidade e qualidade de produtos panificados. *Food Science and Technology*, vol. 25, no. 4, pp. 802-806. <https://doi.org/10.1590/S0101-20612005000400028>.

FOUST, A.S., WENZEL, L.A., CLUMP, C.W., MAUS, L. & ANDERSEN, L.B., 1982. *Princípios das operações unitárias*. Rio de Janeiro: LTC - Livros Técnicos e Científicos Editora S.A., 682 p.

- HOSENEY, R.C., 1998. *Principles of cereal: science and technology*. St. Paul: American Association of Cereal Chemistry, 270 p.
- IRAKLI, M., KATSANTONIS, D. & KLEISIARIS, F., 2015. Evaluation of quality attributes, nutraceutical components and antioxidant potential of wheat bread substituted with rice bran. *Journal of Cereal Science*, vol. 65, pp. 74-80. <https://doi.org/10.1016/j.jcs.2015.06.010>.
- MAILHOT, W.C. & PATTON, J.C., 1988. Criteria of flour quality. In: Y. POMERANZ, ed. *Wheat: chemistry and technology*. St. Paul: American Association of Cereal Chemists, vol. II, pp. 69-90.
- MONDAL, A. & DATTA, A.K., 2008. Bread baking: a review. *Journal of Food Engineering*, vol. 86, no. 4, pp. 465-474. <https://doi.org/10.1016/j.jfoodeng.2007.11.014>.
- PIZZINATTO, A., 1997. *Qualidade da farinha de trigo: conceito, fatores determinantes e parâmetros de avaliação e controle*. Campinas: Instituto de Tecnologia de Alimentos, 72 p.
- PRESTON, K.R. & HOSENEY, R.C., 1991. Applications of the extensograph. In: F. RASPER & K.R. PRESTON, eds. *The extensograph handbook*. St. Paul: American Association of Cereal Chemistry, pp. 13-18.
- PRESTON, K.R. & KILBORN, R.H., 1984. Dough rheology and the farinograph. In: B.L. D'APPOLONIA & W.H. KUNERTH, eds. *The farinograph handbook*. St. Paul: American Association of Cereal Chemistry, pp. 38-42.
- RAO, P.H. & RAO, H.M., 1991. Effect of incorporating wheat bran on the rheological characteristics and bread making quality of flour. *Journal of Food Science and Technology*, vol. 28, pp. 92-97.
- SCHMIELE, M., JAEKEL, L.Z., PATRICIO, S.M.C., STEEL, C.J. & CHANG, Y.K., 2012. Rheological properties of wheat flour and quality characteristics of pan bread as modified by partial additions of wheat bran or whole grain wheat flour. *International Journal of Food Science & Technology*, vol. 47, no. 10, pp. 2141-2150. <https://doi.org/10.1111/j.1365-2621.2012.03081.x>.
- SEHN, G.A.R. & STEEL, C.J., 2017. Classification of whole wheat flour using a dimensionless number. *Journal of Food Science and Technology*, vol. 54, no. 12, pp. 3827. <https://doi.org/10.1007/s13197-017-2811-5>. PMID:29085125.
- TIPPLES, K.H., MEREDITH, J.O. & HOLAS, J., 1978. Factors affecting farinograph and baking absorption II. Relative influence of flour components. *Cereal Chemistry*, vol. 55, pp. 652-660.
- TUNCEL, N.B., YILMAZ, N., KOCABIYIK, H. & UYGUR, A., 2014. The effect of infrared stabilized rice bran substitution on physicochemical and sensory properties of pan breads: part I. *Journal of Cereal Science*, vol. 59, no. 2, pp. 155-161. <https://doi.org/10.1016/j.jcs.2013.12.003>.
- VUOLO, J.H., 1996. *Fundamentos da teoria de erros*. 2. ed. São Paulo: Edgard Blücher, 264 p.
- ZHANG, T., QIU, X., YAO, Y., FAN, M., QIAN, H., WANG, L. & LI, Y., 2025. Water-extractable arabinoxylan improves the properties of gluten during freeze-thaw cycles in steamed bread. *Lebensmittel-Wissenschaft + Technologie*, vol. 228, pp. 118123. <https://doi.org/10.1016/j.lwt.2025.118123>.
- ZHAO, Z., LI, L., LI, W., TIAN, Y., ZHANG, Y., ZHANG, Y., IBBA, M.I., HE, Z., HAO, Y. & TIAN, W., 2025. Rapid evaluation of Farinograph and Extensograph characteristics in bread wheat using near-infrared spectroscopy and chemometrics. *Food Research International*, vol. 218, pp. 116915. <https://doi.org/10.1016/j.foodres.2025.116915>. PMID:40790638.