Design of a quality index for the objective evaluation the quality of breads. Application to wheat breads using selected bake off technology for bread making.

D. Curic[a,*], D. Novotni[a], D. Skevin[a], C. M. Rosell[b], C. Collar[b], A. Le Bail[c], I. Colic-Baric[a]

[a]*Faculty of Food Technology and Biotechnology, University of Zagreb*

Pierottijeva 6, HR-10000 Zagreb

[b]*Institute of Agrochemistry and Food Technology, IATA-CSIC, POBox 73, Burjasot 46100 Valencia, Spain*

[c]*ENITIAA-UMR CNRS GEPEA (6144), ENITIAA, Rue de la Géraudière, BP 82225, 44322 Nantes Cx 3, France*

Abstract

Bread quality index was established using the instrumental analysis of bread parameters that influence the consumers' acceptability. The instrumental methods that describe bread appearance, structure and texture have been chosen in order to enable the identification and quantification of main discrepancies of wheat bread produced by different processes such as fully baked frozen bread (FBF), partially baked frozen (PBF) and bread from unfermented frozen dough (UFD) in comparison to bread baked conventionally (CON). The quality index was calculated as a sum of grouped linearly normalized variables multiplied by group factor of significance and relatively to the CON bread. The significant linear correlation was established between instrumental and descriptive sensory analysis of bread appearance (r=0.966), crumb structure (r=0.731), crust appearance (r=0.691) and texture (r=0.664). The presented quality index could be very useful for bread producers when innovative production processes are applied.

Keywords: Bread; Quality index; Texture; Freezing process; Bake off technology

*****Corresponding author. *E-mail address*: dcuric@pbf.hr

1. Introduction

There are different approaches to the product quality assessment: transcendent, product-based, user-based, manufacturing-based and values based (Garvin, 1988; Pickel, 1989). Some are based on the stand point of the product attributes “what the product is“ and the others on the consumers stand point – ”what a consumer gets“, how the product is perceived by the individual. That is similar to the criteria based on intrinsic and extrinsic factors developed by Bech, Juhl, Hansen, Martens & Anderson (2000) who modelled the relationship between the subjective quality as perceived by consumer and the objective quality as a help in product development. The objective quality is constituted of the total measurable or documentary attributes of a product (Grunert, Jeepesen, Risom, Sonne, Hansen & Trondsen, 2002). Food quality besides product attributes concerns also the production system, how much energy is used, or how the raw materials are produced, but to the consumers it is proven that sensory quality of bread is more important (Kihlberg, Johansson, Kohler & Risvik, 2004).

Bakery products have a short shelf-life, and the loss of freshness has a negative influence on product quality and consumer acceptance. The staling process involves decrease in the mobility of water due to reassociation of polymers, and crystallization of amylopectin (Baik & Chinachoti, 2000; Gray & BeMiller, 2003). One of the approaches to increase bread shelf-life up to twelve months is freezing that can be applied before proofing, to the partially baked bread or at fully baked bread (Rosell & Gomez, 2007). Bake off technology that consists in producing bread from industrial refrigerated or frozen or non frozen bakery goods and retailing them to the bakery shops and supermarkets for the final baking, has many advantages and among them the standardization of product quality is very important. Frozen partially baked bakery products are among the leading products in terms of innovation in the bread industry. If the process is optimized, obtained bread has sensory and textural properties close to the bread obtained by a conventional method (Bárcenas, Benedito, & Rosell, 2004; Barcenas & Rosell, 2005).

One of the major problems of the part-baked and frozen bakery product is crust flaking (Le Bail, Monteau, Margerie, Lucas, Chargelegue & Reverdy, 2005). Crust flaking can be related to mechanical damages due to the intense thermomechanical shock during chilling–freezing and final baking. Furthermore, many studies have reported that frozen part-baked bread has a smaller loaf volume, a rougher crust and a more compact crumb due to the processing conditions, especially freezing conditions (Carr, Rodas, Della Torre & Tadini, 2006; Bárcenas, Benedito, & Rosell, 2004; Bárcenas & Rosell, 2007).

The quality of bread made from frozen dough is influenced by dough formulation, as well as process parameters such as dough mixing time (Rouille, Le Bail, & Coucoux, 2000), freezing rate, storage duration, and thawing rate (Inoue & Bushuk, 1991; Le Bail, Havet, & Pasco, 1998; Lu & Grant, 1999; Neyreneuf & Delpuech, 1993). Several problems in the production of bread from frozen dough have been described, mainly reduced yeast activity, prolonged fermentation time, and loaf volume lowering (Inoue & Boshuh, 1992; Rosell & Gomez, 2007) mostly due to the physical damage of the protein network (Varriano-Marston, Hsu, & Mahdi, 1980) and the yeast deterioration.

The bread freshness can be assessed through texture analysis (Armero & Collar, 1998). The textural profile can be identified instrumentally by universal textural instrument or sensory measuring attributes from consumers approach. Brady & Mayer (1985) obtained low correlation coefficients between sensory and instrumental analysis of textural attributes of rye and French bread. Nevertheless, it is was established by Gambaro, Varela & Gimenez (2002) that instrumental cohesiveness positively correlated to the soft center, softness, stickiness, and sensory chewiness, visual dryness, oral hardness and manual hardness. According to Collar & Bollaín (2005), a good accordance between sensory and instrumental patterns of bread crumb texture during aging of enzyme supplemented breads was observed. In research of Wang, Zhou, & Isabelle (2007) good correlation between the sensory evaluation and instrumental analysis of bread supplemented with green tea extract was set in colour intensity determination but not in porosity determination while the correlation coefficients for the hardness were relatively low for the trained panelists and high for the untrained panelists.

The aim of this study was to establish a methodology allowing the global assessment of the quality of bread. For this purpose, a quality index has been designed and is evaluated by comparing breads made in different conditions. The white wheat breads with extended keepability produced by bake off technology were used as test samples. The physicochemical characteristics and the freshness of bread were determined instrumentally and sensory in order to find the relation of quantitative expression of the product quality relatively to the conventionally produced bread. Physical parameters such as specific volume, shape, crumb to crust ratio, crust flaking, crust hardness, crumb cell distribution and crumb firming were determined instrumentally. Descriptive sensory analysis encompassing appearance, structure, texture and flavour parameters in order to link technological and sensory quality was performed.

2. Materials and methods

2.1. Laboratory baking

For bread preparation wheat flour (chemical composition and rheological properties determined by ICC Methods) obtained from Moulins Soufflet Pantin, France; improver consisting of emulsifier, enzymes and ascorbic acid gained from Puratos, Belgium; fresh compressed yeast (*Saccharomyces cerevisae*) from Kvasac, Croatia (Lesaffre Group, France); salt from Solana Pag, Croatia and tap water were used.

Dough was mixed in Diosna SP40F spiral mixer 2 minutes at 90 rpm and 7 minutes at 180 rpm, divided automatically by Werner Pfleiderer (WP, Germany) divider, proofed in WP proofing cabinet and baked in WP Rototherm oven.

The baking formulation for conventional (CON) bread was (weight bases): flour 100 %, water 58 %, salt 2 %, compressed yeast 5 %, and improver 1 %. After mixing, the dough rested for 10 minutes, it was divided into pieces 70 g and rounded. Dough pieces were placed in proofing cabinet at 35 °C, 95 % RH for 60 minutes and baked at 230 °C for 17 minutes with 0.5 l steam at start.

A portion of fully baked breads was frozen ("Fully baked and frozen", FBF) in a freezer at – 22 °C and stored at – 18 °C in plastic bags for 30 days. FBF breads were unfrozen at room temperature 60 minutes before analysis.

Partially baked and frozen (PBF) breads were prepared according to the following formulation: flour 100 %, water 52 %, salt 2 %, compressed yeast 2 %, and improver 1 %. Dough was divided at 70 g pieces, rounded, and placed in proofing cabinet at 34 °C, 95 % RH for 105 minutes. Breads were partially baked at 190 °C for 3 minutes with 0.2 l steam at start and at 165 °C for 14 minutes. Breads were cooled at room temperature 30 min, frozen at -22 °C, and kept at – 18 °C for 30 days. Part-baked breads were unfrozen at room temperature for 10 min and finally baked at 230 °C for 10 minutes without steam.

The formulation for unfermented frozen dough (UFD) was as following: flour 100 %, water 56 %, salt 2 %, compressed yeast 5 %, and improver 3 %. After mixing and dividing, dough was frozen at - 22 °C, and kept at – 18 °C for 30 days. After 60 minutes of thawing at room temperature, dough was proofed and baked in the same manner as CON bread.

2.2. Instrumental analysis

After 1 h of cooling at room temperature, bread was subjected to the following analysis: specific volume, shape, crumb to crust ratio, crust flaking, crumb cell analysis, and texture analysis. Moisture content was determined according to ICC Standard Method 110/1.

Bread volume was determined by a rapeseed displacement method (AACC Standard 10-05) and the specific volume (volume to mass ratio) was calculated. Bread height and diameter was measured by a calliper and the shape (height to diameter ratio) was calculated. For crumb to crust ratio determination, crust was separated from the crumb using the razor blade. The differentiation between crust and crumb is very subjective and may vary from one person to the other one. In our case, the crust was considered as the dried and significantly coloured material located at the outer zone of the bread. Crumb to crust ratio is expressed as weight ratio on dry basis.

Crust flaking test was carried out in specific crushing system developed by Le Bail et al (2005). Bread was crushed on its flanks and on its base by 30 % of its diameter and height in crushing system. Pieces of the crust were collected and weighted. A digital picture of crust pieces was taken. Using an UTHSCSA Image Tool 3.0 Software, area of crust pieces was measured. The result is expressed as a weight ratio (weight of crust lost / weight of bread, g /100 g) and as the classes of crust pieces size.

Crumb cells were analyzed by scanning longitudinal section of bread sample, 12.5 mm thick, on flatbed scanner (CanoScan 4400F). Images were analyzed by Image J software according to Gonzales-Barron & Butler (2006). Number of cells in cm^2 and ratio of cell area and total area was calculated.

Crust penetration test was carried out on 10 mm thick and 25 mm wide crust pieces from bread top using the 6 mm stainless steel probe and Texture Analyser TA.HDplus (Stable Micro Systems, UK) with 30 kg load cell (Crowley et al, 2002). Compression test mode was used with test speed 1.7 mm/s. The crust hardness is expressed as force (in N) needed to penetrate the sample.

Bread firmness is a force necessary to attain a given deformation and sensory as a force required to compress a substance between incisor teeth (Carr & Tadini, 2003). Crumb firmness was determined according to the AACC Method 74-09 on TA.HDplus Texture

Analyzer (Stable Micro Systems, UK) with a probe 36 mm diameter using a 30 kg load cell. Two slices from the middle 12.5 mm thick were stacked together for each test. Crust was removed just before testing. Sample was compressed by 40 % at speed rate 1.7 mm/s. The firmness is reported as the force (in g) required compressing the sample by 25 % of its original width.

2.3. *Sensory analysis*

Product sensory profile was described by appearance, structure, texture and flavour. The same quality parameters determined instrumentally were evaluated by descriptive sensory analysis (Table 1) with additional evaluation of bread flavour. The most important words for description of bread sensory profile were selected by 6 trained panellists according to ISO 11035:1994(2) and Carr & Tadini (2003). Unstructured 10 cm long scale anchored with "weak" (0) and "strong" (10) was used to attribute intensity. The assessors placed a mark on the line to indicate degree of intensity. Numerical values are attributed by measuring the distance in millimetres between the mark made by assessor and the left hand end of the line and multiplied by factor of significance: 2 for shape and appearance, 3 for crust appearance, 3 from crumb structure, 3 for texture and 9 for flavour that were taken from DLG-Prüfschema (BIB-Ulmer Spatz, 2006) and adjusted for the products made by bake off technology. Sensory score was calculated relatively to the reference bread that was CON bread. Sum of mean intensity values multiplied by the factor of significance was divided by the sum of mean intensity values multiplied by significance factors for reference bread.

2.4. *Quality index expression*

The results obtained by instrumental analysis were normalized by linear transformation according to Molnar (1988) and Schulz & Köpke (1997). The maximum measured value is ascribed to 1, and the minimum value to 0 in the case of desirable attribute, and vice versa for undesirable attribute. The variables are normalized following the equations (Molnar, 1988):

$$z_i = \frac{x_i - x_{\min}}{x_{max} - x_{\min}} \quad \text{if } x_{max} = x_{opt}$$

$$z_i = \frac{x_{\max} - x_i}{x_{max} - x_{\min}} \quad \text{if } x_{min} = x_{opt}$$

Where “x” designs parameters such as specific volume (cm^3/g); shape (height/diameter) (mm/mm); crumb to crust ratio (g/100g db); moisture content (%); crust flaking (g/100g); crumb cell area/total measured area; cell number in cm^2; crumb firmness (N) or crust hardness (N).

The quality index was calculated as a sum of grouped normalized variable multiplied by factor of significance for group of attributes (2 for shape and appearance, 3 for crust appearance, 3 for crumb structure, and 3 for texture), relatively to the CON bread:

$$QI = \frac{\left(2\times\sum z_{sa} + 3\times\sum z_{ct} + 3\times\sum z_{cb} + 3\times\sum z_{tx}\right)_{sample}}{\left(2\times\sum z_{sa} + 3\times\sum z_{ct} + 3\times\sum z_{cb} + 3\times\sum z_{tx}\right)_{CON}} \qquad \textbf{\textit{(3)}}$$

where

z_{sa} is for shape and specific volume (cm^3/g),

z_{ct} for crust flaking (g/100g) and crumb to crust ratio (g/100g db),

z_{cb} for crumb cell number in cm^2 and cells area / total area,

z_{tx} for crumb firmness (N) and crust hardness (N).

2.4. Statistical analysis

All measurements were done at least in duplicate. The results are expressed as average values. The software Statistica 7.1 (StatSoft Inc, USA) was used for the statistical analysis of the data.

3. Results and discussion

Wheat flour used in experimental baking had rather low protein content but good Alveograph properties for bread-making (Table 2). Farinogram showed good water absorption, short dough development time and good stability. Amylolitic activity of the flour was low; therefore, the improver with amylolytic enzymes was added. Furthermore, ascorbic acid in improver helped enhancing plastic-elastic features of dough.

3.1. Instrumentally determined bread appearance, structure and texture

Analysis of variance (ANOVA) revealed that samples produced by different process (CON, FBF, PBF and UFD) showed significant differences in terms of following instrumentally determined physicochemical attributes: moisture ($p = 0.0022$), specific volume ($p = 0.0009$), crumb to crust ratio ($p = 0.0117$), crust flaking ($p = 0.0052$), crust hardness ($p = 0.0001$), and crumb firmness ($p < 0.0001$) (Table 3). There was no statistical significant difference in the shape ($p = 0.4404$) and crumb cell distribution (cell area/total area; $p = 0.4097$, and number of cells per cm^2; $p = 0.0605$) between groups of bread samples.

Partially baked frozen bread revealed by instrumental analysis significantly lower specific volume ($p = 0.05$) than the conventional bread. That is mostly in agreement with Carr et al (2006), who revealed that frozen part-baked French bread had a lower specific volume and weight than fresh bread; but that frozen storage did not influence water content and crumb porosity. Frozen dough bread did not show significant difference in specific volume in comparison to CON but the bread height to diameter ratio was lower. It was found that the bread height and specific volume are strongly influenced by the amount of the liquid that is released from the frozen dough during thawing (Seguchi, Nikaidoo, & Morimoto, 2003).

Crust flaking and crumb to crust ratio were analyzed as important quality factors in bake-off technology. The results are shown in Table 3. Crust was thick about 2 mm and it formed 35-40 % of weight (dry basis) of the baked bread samples. In the case of frozen dough crumb to crust ratio was the lowest. It was found that the crust flaking increased with bread freezing since of FBF and PBF breads it was significantly higher than for CON bread. The flakes classification by size revealed that in FBF bread 18 % of flakes were sizing 10 – 100 mm^2 and 80 % were smaller than 10 mm^2; 10 % of PBF bread flakes were sizing 10 – 100 mm^2 and 89 % were smaller than 10 mm^2 in comparison to CON and UFD bread where 98 % of flakes were smaller than 10 mm^2. This indicates that intensive thermo-mechanical treatment of the bread during freezing, thawing and re-baking caused crust drying and searing, which resulted in the increased crust flaking.

Image analysis of the crumb revealed that the ratio of total cell area and total measured area of the FBF was similar to CON, but in the UFD and PBF it was lower (Table 3). However, number of crumb cells per cm^2 was higher in PBF and UFD than in CON but the cells were smaller. This indicates that freezing influenced the cell distribution in the way that cells were higher in number but smaller in size. This is probably the result of proofing conditions and decreased yeast activity as it was found by Baardseth, Kvaal, Lea, Ellekjaer & Faerestad (2000). This could be also explained by finding of Barcenas & Rosell (2006a,b) that changes occurred due to ice crystals growth during storage time can damage crumb structure resulting in more compact crumb.

Crust penetration test revealed that the CON bread had the highest crust hardness (9.09 N), UFD following, than FBF and PBF the lowest (4.3 N) (Table 3). Process of freezing and thawing influenced negatively the crust hardness.

Frozen bread and part-baked frozen bread especially had significantly higher crumb firmness than conventional bread while bread baked from frozen dough had the lowest firmness (Table 3). That is in agreement with the results obtained by Ribotta, Perez, Leon & Anon (2004) indicating that the dough freezing and storage at -18 °C causes reduced dough firmness and elasticity.

3.3 Results of sensory analysis

The most favoured bread by the panellists was the CON bread (Fig 2). The mean scores for bread samples obtained by descriptive sensory analysis of the panel for CON bread was reported 1.00; FBF 0.83; PBF 0.84 and UFD 0.96 (Table 4). By analysis of variance the significant difference in overall sensory quality between breads produced by different processes was proven at level $p = 0.01$ and $p = 0.001$ and no significant difference between panellists was found. The results of mean scores for selected attributes with standard deviation are graphically presented in Fig. 2. FBF bread was the only sample with changed intensity of flavour. Freezing of FBF bread resulted in decreased sensation of saltiness and increased sweet savour. Further more, freezing influenced the crumb colour appearing brighter and bread juiciness was less pronounced. The crust was broken and the flaking was high. PBF bread had significantly lower volume, the crust was more dry and detached from the crumb, and crust colour was uneven. The crust flakiness was also high as shown by mechanical crushing test. UFD bread was very similar to the conventional and it had very soft crumb. In all bread samples saltiness was too pronounced and therefore salt content should be reduced.

3.4. Quality index of bread samples

The quality index of breads was established in the following order: CON > UFD > FBF > PBF (Table 4). The quality of conventionally produced bread was evaluated as the best while UFD and FBF were following very closely. The softness of the UFD bread crumb as well as low crust flaking contributed the most to its high rating which was confirmed by descriptive sensory analysis. PBF bread was evaluated with the lowest quality index due to low specific volume and porosity, high flaking and high initial crumb firmness. This discrepancy from conventional bread was strongly distinguished by instrumental analysis. The correlation between instrumentally determined QI and sensory score (DSA) was low ($r = 0.536$) which is due to the omission of flavour analysis by instrumental methods but ranking of breads is the same by both methods (Table 4).

4. Conclusion

The quality variation of bread produced by different processes can be described relatively to the reference sample with a quality index. Presented quality index is based on the instrumental analysis of selected parameters that are strongly linked to the consumers' acceptance. In the case when innovative bread making process such as bake off technology is applied, the instrumental analysis could give to producer valuable information considering the bread appearance, structure and texture since the deviations in product quality are easily quantified. Instrumental methods are suitable for routing testing as well. Good linear correlation between the instrumental analysis and the results of descriptive sensory analysis was proven for bread appearance (r = 0.966), and lower for crust appearance (r = 0.694), crumb structure (r = 0.731) and texture (r = 0.664). When the change in production process or formulation strongly influences product flavour it is necessary to make sensory analysis but when physical characteristics are changed instrumental determination gives more reliable quantitative information on product quality.

The presented model of the quality index could be tailored according to the users need. The next step in quality index expression established on the instrumental determinations would be a method development for aroma and taste identification and quantification since bread flavour effects the consumers' acceptability the most.

Although there are many papers published for description of overall quality (Molnar, 1988; Molnar, 1995; Schulz & Köpke, 1997), pea quality (Bech et al, 2000), Australian tea (Caffin, D'Arcy, Yao & Rintoul, 2004), water (Jin, Wang & Wei, 2004), this is the first work on quality index of bakery products and it could be applied for different types of bakery products.

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References

American Association of Cereal Chemists (2000). *Approved methods of the AACC* (10th Ed.), St. Paul, MN: The Association.

Armero, E., & Collar, C. (1998). Crumb firming kinetics of wheat breads with anti-staling additives. *Journal of Cereal Science, 28,* 165-174.

Baardseth, P., Kvaal, K., Lea, P., Ellekjaer, M. R, & Faerestad, E. M. (2000). The effects of bread making process and wheat quality on French baguettes. *Journal of Cereal Science, 32,* 73-87.

Baik M., & Chinachoti, P. (2000). Moisture redistribution and phase transitions during bread staling, *Cereal Chemistry, 77,* 484–488.

Bárcenas, M. E. & Rosell, C. M. (2006a). Different approaches for improving the quality and extending the shelf life of the partially baked bread: low temperatures and HPMC addition. *Journal Food Engineering*, *72*, 92-99.

Bárcenas, M. E., & Rosell, C. M. (2006b). Effect of frozen storage time on the bread crumb and aging of part baked bread. *Food Chemistry*, *95,* 438-445.

Bárcenas, M. E., Benedito C., & Rosell, C. M. (2004). Use of hydrocolloids as bread improvers in interrupted baking process with frozen storage. *Food Hydrocolloids*, *18***,** 769–774.

Bárcenas, M. E., & Rosell, C. M. Different approaches for increasing the shelf life of partially baked bread: low temperatures and hydrocolloid addition. (2007). *Food Chemistry*, *100/4,* 1594-1601.

Bech, A. C., Juhl, H. J., Hansen, M., Martens M., & Andersen L. (2000). Quality of peas modelled by structural equation system. *Food Quality and Preferences, 11,* 275-281.

BIB-Ulmer Spatz (2006). Perfekte Brotqualität: Brotfehler erkennen und vermeiden. BIB-Ulmer Spatz für das Backgewerbe in Zusammenarbeit mit der BFEL und der DLG. Backgewerbe, Auflage 2/2006. Available at http://www.backmittel.de/BBZ/pdf/Brotqualitaet.pdf

Brady, P. L., & Mayer, S. M. (1985). Correlation of sensory and instrumental measures of bread texture. *Cereal Chemistry***,** *62***,** 70–72.

Caffin, N., D'Arcy, B., Yao, L, Rintoul, G. (2004) Developing an index of quality for Australian tea. Rural Industries Research and Development Corporation, Australian Government. RIRDC Publication No. 04/033, RIRDC Project No. UQ-88A.

Carr, L. G., & Tadini, C. C. (2003). Influence of yeast and vegetable shortening on physical and textural parameters of frozen part baked French bread. *Lebensmittel-Wissenschaft und -Technologie*, *36*, 609-614.

Carr, L. G., Rodas, M. A. B., Della Torre, J. C. M., & Tadini, C. C. (2006). Physical, textural and sensory characteristics of 7-day frozen part-baked French bread. *Lebensmittel-Wissenschaft und -Technologie*, *39*, 540-547.

Collar, C., & Bollaín, C. (2005). Impact of microbial transglutaminase on the staling behaviour of enzyme-supplemented pan breads. *European Food Research and Technology, 221,* 298–304.

Crowley, P., Schober, T., Clarke C., & Arendt, E. (2002). The effect of storage time on textural and crumb grain characteristics of sourdough wheat bread. *European Food Research and Technology, 214,* 489–496.

Gambaro, A., Varela, P., & Gimenez A. (2002). Textural quality of white pan bread by sensory and instrumental measurements. *Journal of Texture Studies*, 33, 401-413.

Garvin, D. A. (1988). Concepts and definitions. In D. A. Garvin, *Managing Quality*, *the Strategic and Competitive Edge*, (pp. 39-68). New York: The Free Press A Division of Simon & Schuster Inc.

Gonzales-Barron, U., & Butler, F. (2006). A comparison of seven thresholding techniques with the k-means clustering algorithm for measurement of bread-crumb features by digital image analysis. *Journal of Food Engineering*, *74,* 268-278.

Gray, J. A., & BeMiller J. N. (2003). Bread staling: molecular basis and control. *Comprehensive Reviews in Food Science and Food Safety, 2,* 1–21.

Grunert, K. G., Jeepesen, L. F., Risom, K., Sonne, A-M., Hansen, K., & Trondsen, T. (2002). Market orientation in Industry and value chain levels: Concepts determinants and consequences. *Journal of customer behaviour, 1(2),* 167-194.

Image J software developed by W. Rasband, Research Services Branch, National Institute of Mental Health, Bethesda, Maryland, USA. Available at http://rsb.info.nih.gov/ij/download.html.

Inoue, Y., & Bushuk, W. (1991). Studies on frozen doughs. I. Effects of frozen storage and freeze–thaw cycles on baking quality and rheological properties. *Cereal Chemistry, 68***,** 627–631.

Inoue Y., & Bushuk, W. (1992). Studies on frozen doughs. II. Flour quality requirements for bread production from frozen dough. *Cereal Chemistry, 69(4),* 423-428.

International Association for Cereal Chemistry. ICC-Standard No 107/1 Determination of the “Falling Number” according to Hagberg – as a Measure of the Degree of Alpha – Amylase Activity in Grain and Flour, Approved 1968, Revised 1995.

International Association for Cereal Science and Technology. ICC-Standard No 116/1 Determination of the Sedimentation Value (according to Zeleny) as an Approximative Measure of Baking Quality, Approved 1972, Revised 1994. Vienna: The Association.

International Association for Cereal Science and Technology. ICC-Standard No.104/1 (1990). Determination of Ash in Cereals and Cereal Products, Approved 1960, Revised 1990. Vienna: The Association.

International Association for Cereal Science and Technology. ICC-Standard No.105/2 (1994), Determination of Crude Protein in Cereals and Cereals Products for Food and Feed, Approved 1980, Revised 1994. Vienna: The Association.

International Association for Cereal Science and Technology. ICC-Standard No.106/2 (1984b). Working Method for the Determination of Wet Gluten in Wheat Flour, Approved 1960, Revised 1984. International Association for Cereal Science and Technology. Vienna: The Association.

International Association for Cereal Science and Technology. ICC-Standard No.110/1 (1976). Determination of the Moisture Content of Cereals and Cereal Products (Practical method), Approved 1960, Revised 1976. Vienna: The Association.

International Association for Cereal Science and Technology. ICC-Standard No.115/1 (1992c). Method for using the Brabender Farinograph, Approved 1972., Revised 1992. Vienna: The Association.

International Organization for Standardization: ISO 11035:1994(2) Sensory analysis – Identification and selection of descriptors for establishing a sensory profile by a multidimensional approach. Geneva: The Organization.

Jin, J., Wang, S., Wei, Y. (2004) Ideal Interval Method Based Model for Water Quality Evaluation. Nature and Science, 2 (1): 24-28.

Kihlberg, I., Johansson, L., Kohler, A., & Risvik E. (2004). Sensory quality of whole wheat pan bread – influence of farming system, milling and baking technique. *Journal of Cereal Science, 39,* 67 – 84.

Le Bail, A., Havet, M., & Pasco, M. (1998). Influence of the freezing rate and of storage duration on the gassing power of frozen bread dough. *International Congress of Refrigeration*, Nantes, France, (pp. 16–18).

Le Bail, A., Monteau, J. Y., Margerie, F., Lucas, T., Chargelegue, A., & Reverdy, Y. (2005). Impact of selected process parameters on crust flaking of frozen partly baked dough. *Journal of Food Engineering*, *69,* 503-509.

Lu W. & Grant, L. A. (1999). Effects of prolonged storage at freezing temperatures on starch and baking quality of frozen doughs. *Cereal Chemistry*, 76, 656–662.

Molnar, P. J. (1988). A theoretical model to describe food quality. *Journal of Food Quality*, *12*, 1-11.

Neyreneuf, O. & Delpuech, B. (1993). Freezing experiments on yeasted dough slabs. Effects of cryogenic temperatures on the baking performance. *Cereal Chemistry*, *70*, 109–111.

Pickel, M. (1989). Food quality in general and organic fruit and vegetables in particular. *IFOAM Bulletin for Organic Agriculture*, *9*, 9-11.

Ribotta, P. D., Perez, G. T., Leon, A. E., & Anon, M. C. (2004). Effect of emulsifier and guar gum on micro structural, rheological and baking performance of frozen bread dough. *Food Hydrocolloids, 18,* 305-313.

Rosell, C. M., & Gomez, M. (2007). Freezing in breadmaking performance: frozen dough and part- baked bread. *Food Reviews International*, *23*, 303-319.

Rouille, J. A., Le Bail A., & Coucoux, P. (2000). Influence of formulation and mixing conditions on bread making qualities of French frozen dough. *Journal of Food Engineering, 43*, 197–203.

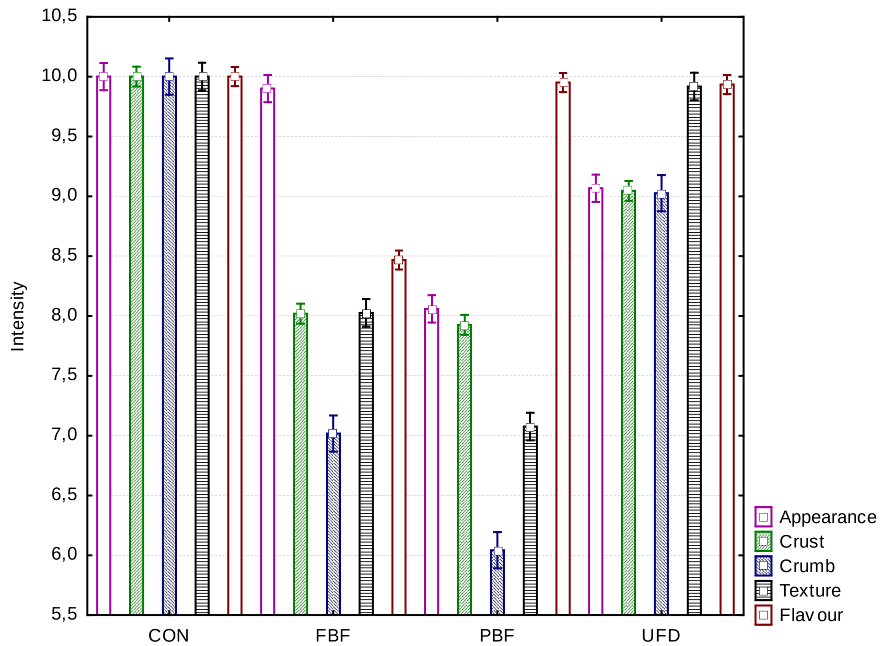
Schulz, D. G., & Köpke, U. (1997) The Quality Index: A holistic approach to describe quality of food. In: Proceedings of the International Conference on Agricultural Production and Nutrition. Boston, Massachusetts, March 19-21, 1997.

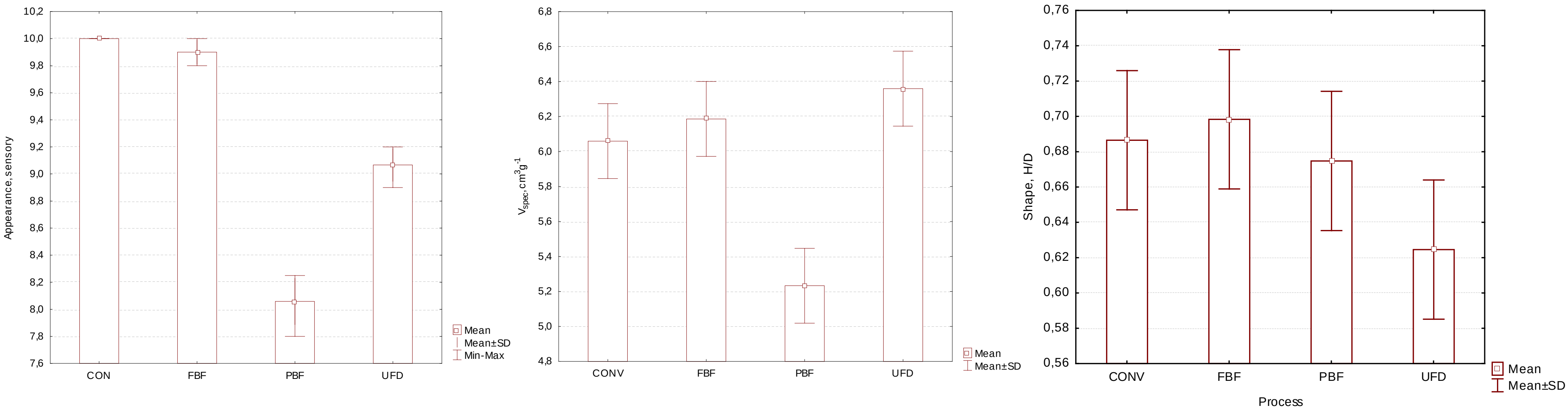
Seguchi, M., Nikaidoo, S., & Morimoto, N. (2003). Centrifuged liquid and breadmaking properties of frozen-and-thawed bread dough. *Cereal Chemistry, 80*, 264-268.

UTHSCSA Image Tool 3.0 software developed by C. D. Wilcox, S. B. Dove, W. D. McDavid and D. B. Greer at the The University of Texas Health Science Center, San Antonio, Texas, USA. Available at http://ddsdx.uthscsa.edu/dig/itdesc.html.

Varriano-Marston, E. K., Hsu, H., & Mahdi, J., (1980). Rheological and structural changes in frozen dough. *Baker's Digest, 54*, 32–34.

452 Wang, R., Zhou, W., & Isabelle, M. (2007). Comparison study of the effect of green tea extract (GTE) on the quality of bread by instrumental analysis and sensory evaluation. *Food Research International*, *40*, 479-479.

455 



Appearance, sensory
10,2
10,0
9,8
9,6
9,4
9,2
9,0
8,8
8,6
8,4
8,2
8,0
7,8
7,6
CON
FBF
PBF
UFD
Mean
Mean±SD
Min-Max
V_{spec}, cm^3g^{-1}
6,8
6,6
6,4
6,2
6,0
5,8
5,6
5,4
5,2
5,0
4,8
CONV
FBF
PBF
UFD
Mean
Mean±SD
Shape, H/D
0,76
0,74
0,72
0,70
0,68
0,66
0,64
0,62
0,60
0,58
0,56
CONV
FBF
PBF
UFD
Process
Mean
Mean±SD

Fig. 1. Whisker plot of bread sensory analysis (score multiplied by factor of significance) for conventional bread (CON), fully baked frozen bread (FBF), partially baked frozen (PBF) and frozen dough bread (UFD), mean value and standard deviation.

Fig. 2. Correlation between sensory determined bread appearance (a), and instrumentally determined specific volume (b) and shape (c) for conventional bread (CON), fully baked frozen bread (FBF), partially baked frozen (PBF) and frozen dough bread (UFD), mean value and standard deviation.

Table 1

Selection of bread attributes for sensory and instrumental analysis, and linkage between sensory and technology quality parameters

Parameter	f	Descriptive sensory analysis	Instrumental analysis
Appearance	2	Volume at the first sight - attractive Shape - regularity, roundness, flatness	Specific volume - Rapeseed displacement method & weighing Shape (diameter/height) -Measurement of bread height and diameter by caliper
Crust appearance	3	Crust flaking by touch and cutting Crust thickness visually	Crust flaking (according to Le Bail et al, 2005) Crumb to crust ratio (weight or volume ratio)
Crumb appearance and structure	3	Crumb cells – number, size, distribution, wall thickness	Crumb cells number per cm^2; cell area / total area
Texture	3	Texture in mouth or by finger Juiceness – degree of perceived moistness Crust hardness by finger	Crumb texture: Bread firmness following the AACC Method 74-09 Moisture content by drying - ICC Standard 110/1 Crust hardness by texture instrument
Flavour (Taste + Aroma)	9	Malty – aromatic sensation that produces a taste or smell reminiscent of toasted grains Alcoholic – characteristic odour of item containing alcohol (ethanol) Buttery – rich smell of melted butter Green-earthy – characteristic odour of fresh earth, wet soil or humus Wheat - flavour typical of wheat kernel treated with boiled water Salty - perception of salinity Standard solution: sodium chloride 5 g/l Sweet - having or denoting the characteristic taste of sugar Standard solution: sucrose 16 g/l Sour - sharp biting taste like the taste of vinegar or lemons Standard solution: tartaric acid or citric acid 1 g/l Bitter - perceived by the back of the tongue and characterized by solutions of quinine, caffeine, and other alkaloids; usually caused by over-roasting. Standard solution: caffeine 0,5 g/l Yeast - aroma of fresh baked bread Bland - lack of taste, flat and neutral Nutty - taste typical of freshly ground hazelnuts Milk - taste typical of fresh milk	

f - factor of significance

Table 2

Physicochemical characteristics of the used wheat flour (Moulins SOUFFLET, Pornic, France, harvest year 2006, stored at – 20°C.

Parameter		**Result**
Water content (%)		14.4
Ash (%)		0.52
Protein (g/100g dm)		9.54
Falling number (s)		450
Sedimentation value (cm^3)		33
Wet gluten (%)		24.9
Gluten index (%)		94.4
Farinogram	water absorption (%)	54.0
	dough development time (min)	2.0
	dough stability (min)	7.3
	dough strength (BU)	58
	degree of softening (BU)	60
Alveogram	tenacity, P (mm)	58
	extensibility, L (mm)	113
	deformation energy, W (10^{-4} J)	211
	curve configuration ratio, P/L	0.51
Amylogram	start of gelatinization (°C)	50.8
	max viscosity (AU)	1,560.0
	temperature at max viscosity (°C)	81.4

Table 3

Physicochemical characteristics of bread samples (CON conventionally baked bread; FBF fully baked frozen; PBF partially baked frozen and UFD unfermented frozen dough) – mean values.

Sample	**Moisture (%)**	**Specific volume (cm^3/g)**	**Shape (h/d)**	**Crumb/ crust (g/100g)**	**Crust flakiness (g/100g)**	**Crust hardness (N)**	**Crumb firmness (N)**	**Cells Area/Total Area**	**No Cells/ cm^2**
CON	31.04 (0.028)	6.059 (0.255)	0.686 (0.009)	1.923 (0.035)	0.380 (0.324)	9.092 (0.676)	1.617 (9.808)	0.216 (0.017)	9.80 (0.045)
FBF	30.60 (0.283)	6.184 (0.090)	0.689 (0.003)	1.927 (0.042)	2.024 (0.144)	6.133 (0.140)	2.557 (8.481)	0.220 (0.023)	8.80 (0.273)
PBF	29.44 (0.311)	5.234 (0.146)	0.672 (0.087)	1.870 (0.057)	3.355 (0.751)	7.213 (1.221)	3.424 (8.569)	0.172 (0.033)	12.76 (0.407)
UFD	31.67 (0.099)	6.362 (0.298)	0.625 (0.007)	1.612 (0.084)	0.346 (0.040)	7.383 (0.837)	0.604 (4.746)	0.207 (0.033)	11.36 (0.831)

Table 4

The correlation between quality index (QI) determined instrumentally and score obtained by descriptive sensory analysis (DSA) for conventional bread, fully baked frozen bread (FBF), partially baked frozen bread (PBF) and bread from frozen dough (UFD), r = 0.536.

Sample	**QI**	**DSA**
CON	1	1
FBF	0.977	0.828
PBF	0.523	0.845
UFD	0.999	0.960