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Volatile compounds in whole meal bread crust: The effects of yeast level and fermentation temperature

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ABSTRACT

The influence of fermentation temperatures (8 °C, 16 °C, and 32 °C) and yeast levels (2%, 4%, and 6% of the flour) on the formation of volatile compounds in the crust of whole meal wheat bread was investigated. The fermentation times were regulated to optimum bread height for each treatment. The volatile compounds were extracted by dynamic headspace extraction and analyzed by gas chromatography-mass spectrometry. The results were evaluated using multivariate data analysis and ANOVA. In all crust samples 28 volatile compounds out of 58 compounds were identified and the other 30 compounds were tentatively identified. Higher fermentation temperatures promoted the formation of Maillard reaction products 3-methyl-1-butanol, pyrazine, 2-ethylpyrazine, 2-ethyl-3-methylpyrazine, 2-vinylpyrazine, 3-hydroxy-2-butanone, 3-(methylsulfanyl)-propanal, and 5-methyl-2-furancarboxaldehyde whereas at lower temperature (8 °C) the formation of 2- and 3-methylbutanal was favored. Higher levels of yeast promoted the formation of 3-methyl-1-butanol, 2-methyl-1-propanol and 3-(methylsulfanyl)-propanal, whereas hexanal was promoted in the crust fermented with lower yeast level.

1. Introduction

Recently, higher demand for whole grain products is observed worldwide due to their high nutritional values and protective effects against several chronic diseases (Slavin, Tucker, Harriman, & Jonnalagadda, 2013). Whole meal wheat bread is one of the most consumed whole grain products, however, it has lower consumer acceptability compared to wheat bread made from refined flours (Bakke & Vickers, 2007).

Crust is commonly defined as the drier, darker and harder surface of the bread and distinguishable from the crumb (Lind & Rask, 1991; Westurlund, Theander, & Aman, 1989). The thickness and darkness of the crust are proportional to the time and temperature of baking (Mondal & Datta, 2008; Purlis, 2011; Zanoni, Peri, & Pierucci, 1993). The formation of color and flavor in the crust of bread during baking is mainly a result of Maillard reactions, the non-enzymatic chemical reactions occurring between free amino acids and carbonyl groups of reducing sugars (Hodge, 1953). The reactions depend on the water content, baking temperature, pH, and the content of reducing sugars and free amino acids. The moisture content on the surface of the loaf is usually less than 20% due to the baking process (Vanin, Lucas, & Trystram, 2009) and increases the surface temperature to more than 100 °C which provides suitable conditions for the formation of Maillard reaction products and in turn leads to crust formation (Zanoni et al., 1993). Thus higher content of aldehydes, ketones, furans, pyrazine derivatives, and some other compounds generated from Maillard reactions, were observed in the whole meal bread crust and wheat bread crust compared to the crumb (Bianchi, Careri, Chiavaro, Musci, & Vittadini, 2008; Chang, Seitz, & Chambers, 1995; Jensen, Oestdal, Skibsted, Larsen, & Thybo, 2011; Moskowitz, Bin, Elias, & Peterson, 2012; Seitz, Chung, & Rengarajan, 1998).

The flavor of the bread crust is expected to be more intense than the bread crumb as the crust is exposed to higher temperature than the crumb (Zehentbauer & Grosch, 1998a). Schieberle and Grosch (1991) found 2-acetyl-tetrahydropyridine and 2-acetyl-1-pyrroline with their roasty notes as the most important flavor compounds of wheat bread crust, and they found a higher content of these compounds in the crust compared to the crumb of the same bread. Also, the components 4-hydroxy-2,5-dimethyl-3(2H)-furanone, 2-methylpropanal, 2,3-butanedione, 3-(methylsulfanyl)-propanal,

Abbreviations: OT, Odor Threshold; dPLS, Discriminant Partial Least Squares; GC-MS, Gas Chromatography-Mass Spectrometry; DHE, Dynamic Headspace Extraction.

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2- and 3-methylbutanal, and (E)-2-nonenal were characterized as important odorants in wheat bread crust (Grosch & Schieberle, 1997; Schieberle & Grosch, 1991; Zehentbauer & Grosch, 1998a; Zehentbauer & Grosch, 1998b). The review by Cho and Peterson (2010) also reported that (Z)-2-nonenal, (Z)-4-heptenal, 1-(Z)-5-octadien-3-one, phenylacetaldehyde, (E,Z)-2,6-nonadienal, (E,E)-2,4-decadienal and (E,E)-2,4-nonadienal were other key odorants of wheat bread crust. The contents of Maillard reaction products were higher in fully baked wheat bread compared to the partially baked wheat bread (Poinot et al., 2008).

Zehentbauer and Grosch (1998a, 1998b) evaluated the crust aroma of wheat baguette prepared from two different recipes; conventional and artisan. They found that baguette prepared according to a conventional recipe with short process time (26 g yeast/kg flour, fermented for 160 min at 26 °C) had higher content of 2-acetyl-1-pyrroline, 2-ethyl-3,5-dimethylpyrazine, hexanal, (E)-2-nonenal, and 2,3-butanedione in the crust compared to the crust from an artisan recipe made with low yeast amount (15 g yeast/kg flour), addition of pre-fermented dough and final fermentation in long time at low temperature (18 h at 4 °C). On the other hand, the crust of baguette made due to the artisan recipe had higher content of the aldehydes 3-(methylsulfanyl)-propanal, 2- and 3-methylbutanal, 2-methylpropanal, 2,4-decadienal, and 2-methoxy-4-vinylphenol. The crust of baguette made by conventional recipe had higher intensity of roasty attribute, meanwhile, the crust made by artisan recipe had higher intensity of malty attribute. The attributes of buttery and sour however, were perceived as being similar in intensity in the bread crust made from both recipes.

Information is not available about the influence of fermentation conditions towards the formation of important volatile compounds in the crust of whole meal wheat bread. Therefore, the aim of this work is to investigate to which degree the formation of volatile compounds in the crust of whole meal wheat bread is influenced by fermentation conditions such as yeast amount and fermentation temperature.

2. Materials and methods

2.1. Experimental design

Bread was made from wheat whole meal flour with three levels of yeast corresponding to 2%, 4% and 6% of the flour. The bread dough was fermented at three different temperatures 8 °C, 16 °C and 32 °C. The combination of different yeast levels and fermentation temperatures add up to 9 treatments. Bread with the same treatment was made twice (duplicate) on two consecutive days which made up 18 bread samples in total. The analysis of volatile compounds was carried out in triplicate with a total of 54 samples. The bread samples were named as follow: yeast level (2, 4, or 6); fermentation temperature (8, 16 or 32); treatment duplicate (a or b) and analysis triplicate (1, 2, or 3).

2.2. Wheat grain and whole meal flour

Wheat grains of the variety Øland (organically grown) were purchased from Aurion A/S Milling and Baking Company (Denmark). Protein content was 14 g/100 g, lipid 2.8 g/100 g and ash 1.5 g/100 g. The grains were milled on a Brabender Quadrumat junior laboratory roller mill the day before baking. The particle size of the whole meal was as follows: 27% of the flour had particle size less than 75 μm; 37% between 75 μm and 160 μm; 16% between 160 μm and 250 μm; 8% between 250 μm and 500 μm; 8% between 500 μm and 1000 μm, and only 4% had a particle size bigger than 1000 μm.

The moisture content of the flour was measured on the day of baking (HOH-express, Pfeuffer) and varied from 10.7 to 10.9%. The wet gluten content in the sifted flour with particle size < 160 μm was 27.9% (Glutomatic 2100, Perten) (Method no. 38-12, AACC, 1995). The falling number of whole meal flour was 230 s (Falling Number 1500, Perten) (Method no 107/1, ICC, 1995).

2.3. Yeast

Commercial pressed fresh baker's yeast *Saccharomyses cerevisiae*, SKÆRTOFT MØLLE, an organically produced baker's yeast from Agrano, Germany was used. The yeast was taken from the same batch for all bakings.

2.4. Bread making

The whole meal bread was made according to Nor Qhairul Izzreen, Petersen, and Hansen (2016). 300 g of wheat whole meal (adjusted to 14% moisture content), 192 mL water (30 °C), 4.2 g saccharose, 4.2 g NaCl and 6 g, 12 g or 18 g yeast (corresponding to 2%, 4% and 6% of the flour), respectively were mixed in a bread maker machine (XBM 5, FOVEA A/S, Denmark) and set to knead for 19 min. After kneading, 400 g dough from each batch was transferred to a baking tin and then placed in an incubator at 8 °C, 16 °C or 32 °C, respectively for fermentation. The fermentations were terminated when the doughs reached 8 cm in height. Preliminary tests were carried out to find the optimal fermentation times for each combination of yeast level and fermentation temperature by monitoring the dough height by a web-camera during the fermentations. The optimal fermentation time was the time when each dough reached 8 cm which was the maximum height of dough just before it collapsed (Table 1). The dough was baked at 200 °C for 17 min to a center temperature of 99 °C in a convection oven (Conmatic line, Houno, Brønnum). After baking, the loaves were cooled at ambient temperature for 15 min, then taken out from the baking tin and further cooled on a grate at the same temperature for another hour. The top 0.5 cm of the bread loaf was cut off and taken as the crust sample. The samples were then packed in aluminum foil in a plastic bag and kept frozen at −18 °C for two weeks until analysis.

2.5. Fermentation temperature

The fermentation temperatures of 32 °C, 16 °C and 8 °C were chosen, as these temperatures are realistic in commercial bread production. Most dough fermentations are made within the range of 25-35 °C which is the optimal temperature interval for baker's yeasts (Torija, Rozès, Poblet, Guillamón, & Mas, 2003). In addition, low fermentation temperature (5 to 10 °C) is used in dough retarding (Cauvain, 2007).

2.6. Dynamic headspace extraction

A dry bread crust sample weighing 8 g was cut into pieces (0.5 cm × 0.5 cm × 0.5 cm) and transferred to a 500 mL purge glass

Table 1
Fermentation times for doughs to reach optimal height at combination of fermentation temperatures and yeast concentrations.

Fermentation temperature (°C)	Yeast concentration (% of flour)		
	2	4	6
8	20 h 15 min	8 h 45 min	4 h 50 min
16	7 h 30 min	4 h	3 h
32	2 h	1 h 40 min	1 h 10 min