Correlation of Flavor Profile to Sensory Analysis of Bread Produced with Different *Saccharomyces cerevisiae* Originating from the Baking and Beverage Industry

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ABSTRACT

Aroma is an important quality parameter for wheat bread, and most of the aroma compounds in yeast-fermented bread are caused by the fermentative action of yeast. In this study, the impact of various strains of *Saccharomyces cerevisiae*, originating from the beverage industry, were investigated on the aroma profile of wheat bread. Seven volatiles were analyzed by gas chromatography–mass spectrometry after thermal desorption (GC-MS TD) from the bread crumb. The results showed yeast strain-dependent production of aroma compounds. Descriptive sensory analysis resulted in an overall taste acceptance by the panelists for breads baked with *S. cerevisiae* baker's yeast, T-58, and Blanc. The panel acceptance can be explained by the production of sensory-active compounds such as 3-methyl-1-butanol and 2,3-butandiol. Furthermore, the panelists preferred bread samples with a less bitter ($r = -0.934$, $P < 0.01$) and less cheesy taste ($r = -0.865$, $P < 0.03$). Also the visual aspects play an important role, shown by correlation between the specific volume and the overall appearance ($r = 0.928$, $P < 0.01$). Aroma profile analysis offers a tool for the selection of new yeast strains, increasing the bread variety on the market. Consequently, aroma production as a yeast quality characteristic should be taken into account for the selection of new strains involved in breadmaking.

Although a large amount of aroma compounds are formed during the baking process, fermentation plays a key role in the development of the unique bread flavor (Hui 2006). As a result of the yeast metabolism, a wide range of aroma-active volatiles have been identified (Birch et al. 2013a). Overall, the main groups responsible for bread crumb aroma are alcohols, aldehydes, esters, ketones, and acids. From the beer and wine industry it is common knowledge that the choice of yeast strain is an important parameter to alter flavor perception of the end product (Wondra and Berovič 2001; Swiegers et al. 2006; Pires et al. 2014). Only recently, flavor and aroma profiles have been considered as quality parameters during breadmaking (Cho and Peterson 2010; Birch et al. 2013a, 2014; Pico et al. 2015). This has led to an increasing commercial interest within the field of bread fermentation to change the aroma characteristics of bread. Styger et al. (2011) explained that differences in the genes of *Saccharomyces cerevisiae* strains play a major role in the change of the aroma profiles. The main genes responsible for aroma formation by yeast have been recently investigated by Hazelwood et al. (2008) and belong to the Ehrlich pathway. Another study showed variation in the aroma profile of bread with the application of seven commercial baker's yeasts (Birch et al. 2013a). These modifications might be owing to changes in the gene-regulating mechanisms and pathways of aroma compounds. The formation of 1-propanol, 2-methyl-1-propanol, and 3-methylbutanal from valine and leucine via the Ehrlich pathway was higher in two Belgian baker's yeasts when compared with yeasts produced in other European countries (Birch et al. 2013a). Several carboxylases have been investigated to be important for the catabolism of these branched-chain amino acids as well as the aromatic amino acid phenylalanine (Dickinson et al. 2003). Hence, the activity of these carboxylases in commercial baker's yeasts is strain dependent. Yeast-associated extracellular enzymes such as proteases, lipases, and amylases further influence the aroma profile. The main role of enzymes during breadmaking is the production of flavor precursors. Residual sugars, mainly glucose and fructose originating from amylase activity, are able to participate in the Maillard reaction during baking (Maga and Pomeranz 1974). Proteases increase amino acids and peptide concentrations, which are participating as precursors for aroma production in the Ehrlich pathway, as well as the Maillard reaction. Lipase activity is responsible for the production of short-chain fatty acids and therefore induces changes in lipid composition, and these also contribute to flavor changes (Martínez-Anaya 1996).

A higher yeast quantity can increase the concentration of the aroma compounds 3-methyl-1-butanol, 2-phenylethanol, and 3-hydroxy-2-butanone, as reported by Birch et al. (2013b). 3-Methylbutanal, 3-methyl-1-butanol, phenylacetaldehyde, and 2,3-butandione were predicted to be the most important aroma-active volatiles. An extensive review of the available literature showed that yeast strains indeed influence the aroma profile of fermented products such as beverages (Suárez-Lepe and Morata 2012; Pires et al. 2014). However, only a little attention has focused on the impact of yeast strains on bread aroma. This study investigated how different yeasts originating from the beer and wine industry alter the aroma profile in comparison with baker's yeast. In addition, a descriptive sensory analysis was performed with a trained panel. The present findings further add knowledge to improve the understanding of aroma formation during dough fermentation.

MATERIALS AND METHODS

Materials. The suppliers of the ingredients were Voigtmühle (Illertissen, Germany) for baker's flour, Glacia British Salt (Middlewich, U.K.) for salt, and Vandemoortele (Izegem, Belgium) for palm fat. Instant active dry baker's yeast was obtained from Puratos (Groot-Bijgaarden, Belgium); dry yeasts s-23, T-58, us-05, and wb-06 were supplied by the Fermentis Division of S. I. Lesaffre (Marcq-en-Barul, France). Dry yeast Blanc was supplied from Vinoferm (Brouwland, Beverlo, Belgium). All the yeasts applied in this study belonged to the species *S. cerevisiae*. All chemicals were supplied by Sigma-Aldrich (Arklow, Ireland).

Breadmaking. Breadmaking was performed as previously described by Heitmann et al. (2015) with some modifications. Wheat breads were prepared using 2.2% salt, 1% palm fat, 62% water, and different amounts of yeast (Table I), based on flour weight. The amount of yeast was adapted to the amount of baker's yeast (1.13 E +09 cfu/g) analyzed by the total cell count (Heitmann et al. 2015). Yeast was dissolved in water (25°C) and activated for 10 min. The yeast/water suspension was added to the premixed dry ingredients and the fat. Mixing was performed for 2 min at low speed with a spiral mixer (Mac Pan, Thiene, Italy). A further mixing at higher speed was carried out for 5 min. The doughs were scaled to 500 g, molded, and placed into baking tins, which were proofed (KOMA

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Sunriser, Roermond, the Netherlands) for 85 min (35°C, 75% relative humidity). Baking was carried out for 35 min at 230°C top and bottom temperature in a deck oven (MIWE Condo, Arnstein, Germany), previously steamed with 0.35 L of water. After baking, the bread loaves were directly removed from the tins and cooled down at room temperature for 120 min. Finally, the bread crumb and crust was separated and stored frozen for further analysis.

Technological Bread and Dough Characteristics. Loaf-specific volume and bake loss were analyzed after cooling for 2 h with a Volscan profiler (Stable Micro Systems, Godalmig, U.K.) (Heitmann et al. 2015). A C-cell bread imaging system (Caliber Control International, Warrington, U.K.) was used for the evaluation of the structure of bread crumb. The analysis was also performed with three central slices of three loafs. Parameters investigated by the C-cell system were total number of cells and number of cells/mm² (Heitmann et al. 2015). Rheofermentometer F3 (Chopin, France) measurements were used for the investigation of the carbon dioxide production (V_{total}) and retention during fermentation ($V_{retention}$) (Heitmann et al. 2015).

Extraction of Volatile Aroma Compounds by Thermal Desorption (TD) and Quantification with GC-MS. For the extraction of volatile aroma compounds, samples were prepared by weighing 0.1 g into a clean glass TD tube to concentrate the volatile aroma compounds in a gas stream prior to injection (Turbomatrix 650, Perkin Elmer, Waltham, MA, U.S.A.). Subsequently, the aroma compounds were absorbed at 90°C for 10 min. Quantification of the aroma-active volatiles was made with a gas chromatography mass spectrometer (GC-MS, Agilent 5977B MSD, Agilent Technologies, Santa Clara, CA, U.S.A.) with an Rxi 624-Sil 20 m column and helium as the carrier gas. The details for the temperature profile are start temperature 35°C (4 min) with an increase of 15°C/min to 220°C (hold 1 min). The total run time was 17.3 min. For the detected compounds a database search was conducted. The aroma compounds detected and analyzed in this study by GC-MS TD were ethanol, acetic acid, 3-methyl-1-butanol, isobutyric acid, 2,3-butanediol, 1-hexanol, and 2-phenylethanol.

Sensory Analysis. Descriptive sensory analysis was performed by a trained panel consisting of 15 panelists (10 male, 5 female, aged 25–34 years) using aroma profile analysis. Six months prior to participation in the sensory evaluation, weekly sessions were held to train the panelists to be able to orthonasally recognize 120 selected odorants at different odorant concentrations. Odor qualities and quantities were determined by smelling reference solutions. The performance was assessed via standard procedures for each panelist. All training and sensory analyses were performed in a sensory panel room at 21 ± 1°C. Based on reference aroma solutions with certain concentrations, a "flavor language" was developed to define the specific smell of a compound corresponding to a certain aroma attribute. For descriptive aroma profile analysis, each wheat bread sample was cut into slices (thickness: 2 cm) and presented to the sensory panel. The sensory panel had to sniff the crumbs and describe the odor intensity they perceived on a scale from 0 (not detectable) to 10 (high intensity). For descriptive taste profile analysis, the panelists tasted the bread crumb and scored the intensities of the taste attributes on the same scale. To evaluate the aroma, taste, and overall liking, the panel evaluated the liking of each sample on a 0 (dislike very much) to 10 (like very much) scale. Arithmetic means of each sensory score were calculated.

Data Analysis. Results are shown as average ± confidence interval of at least triplicate measurements. Minitab 16 software was used to carry out statistical analysis. Exploratory data analysis was followed by a multiple comparison procedure of variance (one-way ANOVA) followed by a posthoc Tukey test to describe significant differences at a level of significance of 5% ($P < 0.05$). In addition, Pearson correlation was performed to find linear dependencies between all the various parameters ($P < 0.01$).

RESULTS AND DISCUSSION

Loaf Characteristics. Standard bread quality parameters were analyzed (Table I). *S. cerevisiae* us-05, wb-06, and Blanc showed the least gas production during 3 h of fermentation, indicating a slow fermentation rate. Accordingly, their bread specific volume was significantly lower ($P < 0.05$). A positive correlation between gas production and specific volume was found to emphasize this finding ($R^2 = 0.92$, $P < 0.001$). Because the amount of viable cells was the same for all yeasts, this fact can be mainly explained owing to the applications commonly used for the various yeasts. The used yeasts are normally applied in the production of beer and wine, for which fermentation in general takes place several days, as well as the different substrate used as an energy source. However, the positive results for *S. cerevisiae* T-58and s-23 might be explained by their higher temperature tolerance. They are therefore better adapted to the bread fermentation process.

Analyses of Volatile Aroma Compounds in Bread Crumb. In addition to ethanol, which had the highest amount of volatile aroma compound produced during bread fermentation, many other key aroma components have been identified in the crumb of wheat bread, such as 3-methyl-1-butanol, 2-phenylethanol, and 2,3-buntanedione (Schieberle and Grosch 1991; Gassenmeier and Schieberle 1995). Also, various acids such as acetic acid, butyric acid, valeric acid, and isobutyric acid contribute to the overall aroma (Frasse et al. 1993). Nonvolatile compounds that have an influence on the flavor of wheat bread are lactic acid (originating from sourdough) and salt (Calvel et al. 2001). The corresponding pathways responsible for their formation by *S. cerevisiae* are presented in Figure 1. The resulting concentrations are summarized in Table II. Ethanol concentration showed significant differences in bread crumbs. The highest amount was found in breads baked with *S. cerevisiae* T-58, probably owing to its higher temperature tolerance. *S. cerevisiae* Blanc was expected to show the highest alcohol production, because this yeast is normally used for wine production and has a high alcohol tolerance.

3-Methyl-1-butanol was only detectable in bread samples baked with *S. cerevisiae* baker's yeast, s-23, and T-58. Birch et al. (2014) and Frasse et al. (1993) stated that 2- and 3-methyl-1-butanol are the

TABLE I
Technological Bread Characteristics and Dough Fermentation Parameters[z]

S. cerevisiae	Dosage (%) Based on Flour	Specific Volume (mL/g)	Bake Loss (%)	Number of Cells	Number of Cells/mm²	V_{total} (mL)	$V_{retention}$ (mL)
Baker's yeast	2	3.52 ± 0.15a	10.52 ± 0.21a	5,353 ± 388a	0.57 ± 0.04bc	1,372.0 ± 37.2a	1,229.0 ± 25.5a
s-23	4	2.92 ± 0.02b	11.08 ± 0.26a	4,269 ± 101d	0.54 ± 0.01c	1,030.5 ± 148.0bc	961.5 ± 104.9bc
T-58	2	3.55 ± 0.14a	10.45 ± 0.40ab	5,161 ± 112ab	0.54 ± 0.02c	1,321.0 ± 96.0ab	1,172.0 ± 58.8ab
us-05	6	2.51 ± 0.17c	10.28 ± 0.40ab	4,504 ± 79cd	0.64 ± 0.05b	822.5 ± 61.7c	789.0 ± 49.0c
wb-06	2	2.36 ± 0.03c	9.16 ± 0.58c	4,862 ± 155bc	0.72 ± 0.01a	402.5 ± 8.8d	400.0 ± 9.8d
Blanc	0.5	2.17 ± 0.13c	9.39 ± 0.36bc	4,989 ± 180ab	0.74 ± 0.01a	371.0 ± 184.2d	369.0 ± 184.2d

[z] Values in one column followed by the same letter are not significantly different (at $P < 0.05$). *S.* = *Saccharomyces*; V_{total} = carbon dioxide production; and $V_{retention}$ = carbon dioxide retention.

most important aroma and sensorial compounds in yeast-fermented bread crumb, although they are not significantly influenced by yeast concentration. Nevertheless, they increase when the fermentation time is prolonged (Schieberle and Grosch 1991; Frasse et al. 1993; Gassenmeier and Schieberle 1995). As in alcoholic beverages, 2- and 3-methyl-butanol next to *n*-propanol, iso-butanol, and ethanol are the most significant alcoholic aroma compounds that contribute to a warm mouthfeel and are mainly produced via the Ehrlich pathway (Brányik et al. 2008). Therefore, the final concentration of alcohols is evaluated by the utilization of amino acids and sugar uptake rate. The amino acid composition of the fermentation substrate, the fermentation stage, and the yeast strain consequently have an influence on the biosynthetic pathways. Because the production of the aroma compounds analyzed in this study is related to the Ehrlich pathway, it is noteworthy to mention the *BAP2* gene. This gene controls the expression of branched-chain amino acid permeases, which are responsible for the uptake of leucine, isoleucine, and valine (Grauslund et al. 1995). Kodama et al. (2011) showed a constitutive expression of the *BAP2* gene by using the brewing strain BH-225 at higher temperatures. The consequent higher utilization of valine, leucine, and isoleucine promoted the production of 3-methyl-1-butanol. The temperature dependency was confirmed by Abe and Minegishi (2008), who showed a reduced gene expression at lower temperatures. However, it was demonstrated that for the uptake of all branched-chain amino acids in *S. cerevisiae* the main regulatory signal for the transcriptional induction of *BAP2* is the presence of micromolar amounts of leucine (Didion et al. 1996). Because in this study the flour used was always the same, and therefore the amino acid composition did not change, it is suggested that *S. cerevisiae* us-05, wb-06, and Blanc are lacking the *BAP2* gene. As known from the supplier's specification sheet, *S. cerevisiae* s-23 and T-58 are able to perform a faster fermentation at higher temperatures, which promotes the production of 3-methyl-butanol.

2-Phenylethanol is another sensorially important volatile formed in yeast fermented bread crumb that is characterized by a flowery aroma. Birch et al. (2014) and Frasse et al. (1993) mentioned that it is one of the aroma compounds produced with the highest concentration in bread crumb. This fact could not be confirmed by this

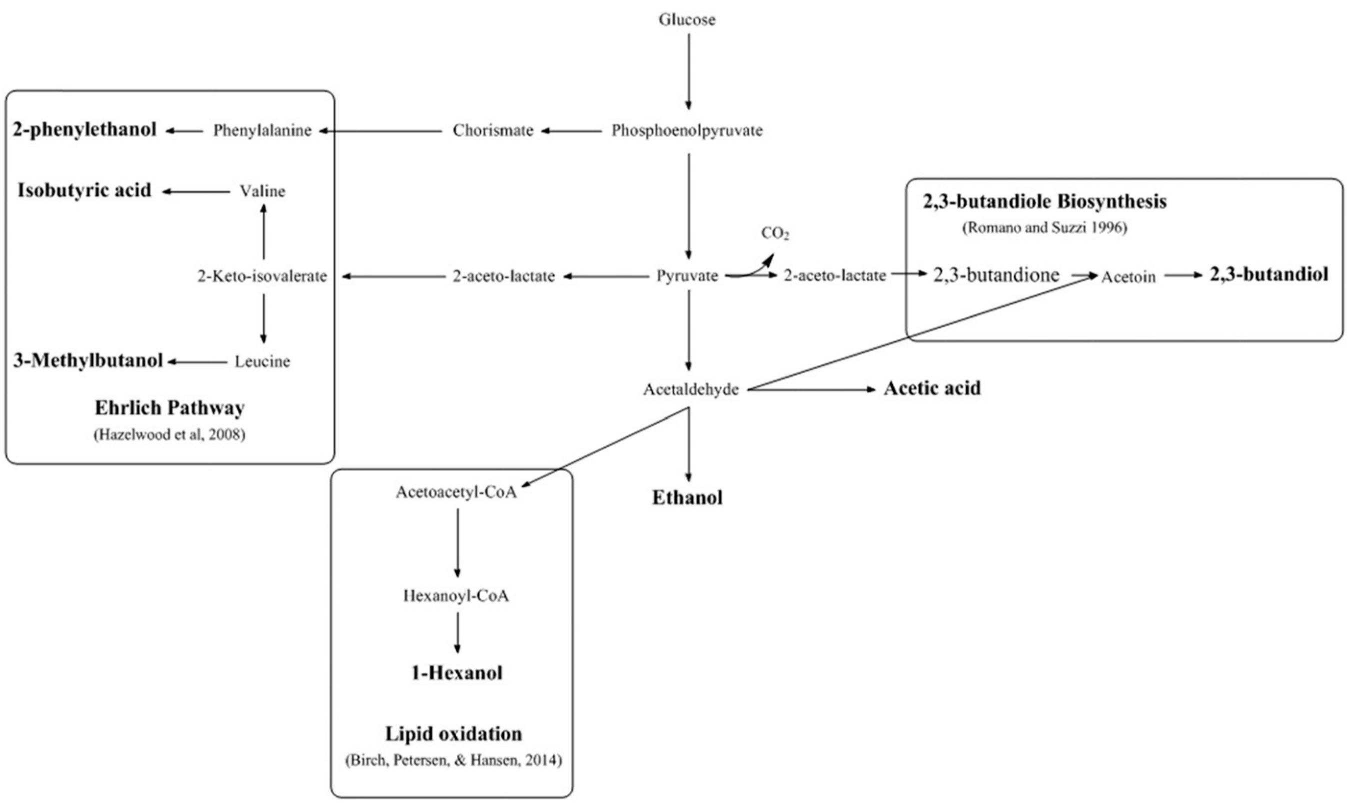

Fig. 1. Yeast metabolism pathways of relevant aroma compounds analyzed during this study.

TABLE II
Concentration and Organoleptic Descriptions of Volatile Aroma Compounds in Bread-Crumb Samples Produced with Different *Saccharomyces cerevisiae* as Determined by GC-MS Thermal Desorption

		Concentration (μg/kg)					
Compound	Organoleptic Description	Baker's Yeast	s-23	T-58	us-05	wb-06	Blanc
Ethanol	Alcoholic, sweet	3,900	4,400	5,500	2,400	2,100	3,200
Acetic acid	Vinegar, pungent, sour	50	130	…	110	110	93
3-Methyl-1-butanol	Alcoholic, fermented, fruity	86	70	64	…	…	…
Isobutyric acid	Acidic, sour, cheesy	20	…	…	…	…	…
2,3-Butanediol	Fruity, creamy, buttery	…	38	62	11	12	…
1-Hexanol	Green, fruity	…	…	…	23	…	…
2-Phenylethanol	Bready, flowery, sweet	15	…	…	…	…	…

study, because 2-phenylethanol was only produced by *S. cerevisiae* baker's yeast to a small degree (15 μg/kg). The formation of 2-phenylethanol in *S. cerevisiae* is through the Ehrlich pathway using the amino acid phenylalanine. Brewer's yeast assimilates phenylalanine slower than other amino acids such as leucine and lysine (Reed and Nagodawithana 1991). Hence, it is not surprising that there was no detectable production of 2-phenylethanol when applying beer yeast strains in a bread system. Birch et al. (2013a) explained this by different carboxylases present in *S. cerevisiae*. Dickinson et al. (2003) found that carboxylases are important for the utilization of branched-chain amino acids (leucine and valine) and aromatic amino acids (phenylalanine) in the Ehrlich pathway. Therefore, the aroma profile of fermented products is yeast strain dependent.

Isobutyric acid is produced by *S. cerevisiae* via the Ehrlich pathway by the utilization of valine. Russell and Stewart (1987) stated that in wort fermentation the availability of high leucine levels stimulates the formation of isobutyric and isovaleric acid. Isobutyric acid was also only produced by *S. cerevisiae* baker's yeast (20 μg/kg).

Production of 2,3-butanediol was only found in breads fermented with the beer yeasts *S. cerevisiae* s-23, T-58, us-05, and wb-06. The responsible pathway for the production of 2,3-butanediol by yeast is the oxidative decarboxylation of 2-acetolactate to 2,3-butanedione, which is further enzymatically reduced to 2,3-butanediol (Wainwright 1973; Romano and Suzzi 1996; see Fig. 1). Maiorella et al. (1983) showed that at higher 2,3-butanediol concentrations, more energy is needed for the active transport mechanism, because it is only slightly lipid-soluble. The active transport mechanism removes the internally produced 2,3-butanediol through the lipid membrane, which could result in an increased ethanol production to provide the necessary amount of adenosine triphosphate. Therefore, *S. cerevisiae* T-58 with the highest ethanol concentration of 5,500 μg/kg shows also the highest production of 2,3-butanediol of 62 μg/kg (r = 0.987, P < 0.01). Because in most beers a high concentration of 2,3-butandione is undesirable, the removal of 2,3-butandione is considered as the rate-limiting step during beer maturation. In beer production, a maximum 2,3-butandione production occurs around 72 h after production, so "aging" is a major step in beer making (Godtfredsen and Otresen 1982). In brewing, there are various strategies to remove 2,3-butandione; the most common practice is to use higher temperatures to enhance the decarboxylation to acetoin and 2,3-butanediol. Therefore, because dough fermentation is performed at higher temperatures than beer fermentation, the production of 2,3-butanediol is favored. 2,3-Butanediole is also the most prominent diol produced during wine fermentation. However, in wine it has only a little sensory significance because it has a minor effect on the odor of the wine and only a slightly bittersweet taste.

Hexanol is a metabolite originating from lipid oxidation and was only found in bread crumb baked with *S. cerevisiae* us-05. Frasse et al. (1992) stated that a higher yeast activity results in a reduced lipoxygenase activity. These enzymes need oxygen to convert fatty acids into the corresponding aldehydes (propanal, pentanal, hexanal, etc.) and alcohols (1-propanol, 1-pentanol, 1-hexanol, etc.); therefore, a lower yeast concentration or activity, and therefore a slower consumption of oxygen, may induce an increase in lipid oxidation products. The only yeast showing a production of 1-hexanol was *S. cerevisiae* us-05. This is in accordance with the relatively low carbon dioxide production during fermentation (Table I).

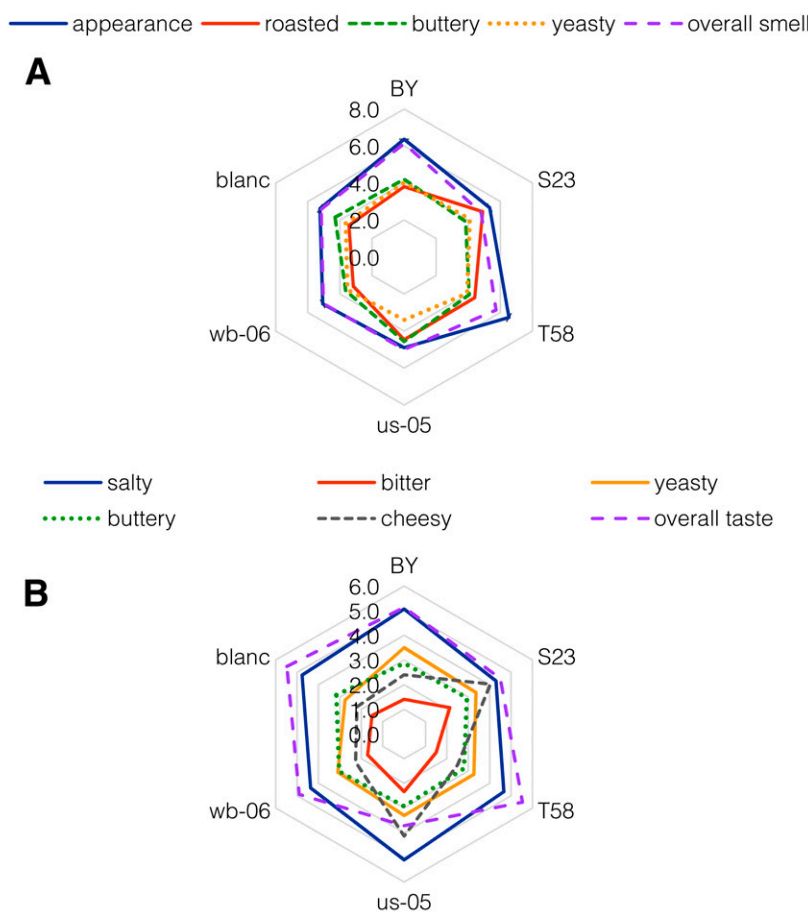

Fig. 2. Sensory analysis of bread crumbs for the smell (**A**) and taste (**B**) of breads baked with different *Saccharomyces cerevisiae* strains on a scale from 0 (not detectable) over 10 (high intensity).

S. cerevisiae Blanc showed generally no flavor production besides acetic acid and ethanol during baking. The production of 1-hexanol depends on the presence and concentration of six-carbon precursors (glucose, fructose, and amino acids) in grapes during wine fermentation (Killian and Ough 1979). Wine yeast is highly adapted to the fermentation of grapes and less well to grain or flour fermentation. This is reflected as well in the inferior loaf characteristics of the corresponding breads.

Descriptive Sensory Evaluation. Eight sensory attributes were collected for the smell and taste of the bread-crumb samples. The dominant characteristics were roasted, salty, buttery, yeasty, bitter, and cheesy. The sensory analysis showed no significant differences for the smell among the panelists (Fig. 2A). In terms of taste, only significant differences for cheesy and bitter were detectable by the panelists (Fig. 2B). The panelist revealed the highest perception of a cheesy aroma for breads fermented with *S. cerevisiae* s-23 and us-05 and a lower perception for breads produced with all of the remaining *S. cerevisiae* strains. The panelist observed a bitter taste in breads fermented with *S. cerevisiae* us-05. The lowest bitter perception was associated to *S. cerevisiae* baker's yeast. The highest panel acceptance in terms of overall taste was found for breads baked with *S. cerevisiae* baker's yeast and T-58 (Fig. 2B). In both breads a high concentration of 3-methyl-1-butanol was detected. Recently, a positive correlation between the aroma of wheat bread and the concentration of 3-methyl-1-butanol and 2-phenylethanol has been shown by Salim-ur-Rehman et al. (2006). Bread fermented with *S. cerevisiae* Blanc also showed a high taste acceptance, although it resulted in the lowest production of aroma compounds. Only ethanol and acetic acid could be detected by GC-MS TD analysis. Some aroma compounds such as hexanal (Martínez-Anaya 1996), butyric acid (Quílez et al. 2006), and higher alcohols are originated from lipid oxidation. 1-Hexanol and 1-octen-3-ol were found to have a negative correlation with consumer preference owing to their unpleasant aroma (Paraskevopoulou et al. 2012). The sensory analysis of the bread revealed *S. cerevisiae* us-05 as the least preferred one by the panelists. This might be linked to the production of 1-hexanol during breadmaking as well as a significantly higher roasted smell and taste.

Correlation Between Aroma Compounds, Technological Bread Characteristics, and Sensory Analysis. Pearson correlation analysis revealed several linear dependencies among the various parameters analyzed. The technological bread parameter number of cells/mm^2 showed a negative relationship to the overall appearance (r = –0.752, P < 0.09). Consumers associate a low number of cells with a dense and dry product, which decreases the acceptance. As expected, a positive correlation was found between the specific volume and the overall appearance (r = 0.928, P < 0.01) as judged by the trained panel. A high specific volume is also related to a soft crumb.

Owing to their alcoholic organoleptic characteristics, another positive correlation was found between the yeasty smell and the ethanol concentration in the bread samples (r = 0.816, P < 0.05) as well as the yeasty taste and the 3-methyl-1-butanol concentration (r = 0.985, P < 0.1). Because 3-methyl-1-butanol is one of the most important aroma compounds within yeast-fermented bread crumbs, it is not surprising that *S. cerevisiae* baker's yeast, s-23, and T-58 reached high acceptance from the panel. These were the only yeasts showing the production of 3-methyl-1-butanol. In general, it is known that high levels of aroma compounds such as alcohol, ketones, and esters (Plessas et al. 2005; Birch et al. 2013b) in combination with low amounts of acids and aldehydes are more accepted from the consumers in sensorial analysis of wheat bread crumb (Quílez et al. 2006). Therefore, the panelists preferred bread samples with a less bitter (r = –0.934, P < 0.01) and less cheesy taste (r = –0.865, P < 0.03). These taste attributes are associated with off-flavors. Furthermore, the panelists observed a more roasted smell for breads having a higher bake loss (r = 0.927, P < 0.01); owing to higher water evaporation and higher bake loss, more heat transfer appears, leading to more Maillard products (Eichner and Karel 1972).

CONCLUSIONS

The influence of various strains of *S. cerevisiae* on the production of volatile aroma compounds in bread crumb by GC-MS TD in combination with a descriptive sensory analysis was investigated. The results revealed strain-dependent aroma formation in a bread matrix and significant differences among the sensory acceptance. Several correlations between aroma profile, sensory characteristics, and technological loaf characteristics were found. Therefore, not only flour composition and quality have to be considered for the breadmaking process. The choice of yeast strain is also an important parameter concerning the impact on aroma profile, sensory acceptance, and technological loaf characteristics. Aroma profile therefore should be added as a new selection criteria for yeast strain development and could be of industrial interest. Because European regulations and consumer acceptance prohibit the use of genetically modified microorganisms, yeast strain selection offers an alternative approach to improve wheat bread quality.

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