

Influence of tempering with ozonated water on the selected properties of wheat flour

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Abstract

Soft and hard wheat samples were tempered using ozonated water (1.5 and 11.5 mg ozone/l). Milling (rate of extraction), rheological (farinograph and extensograph characteristics), chemical (protein, falling number, sedimentation volume), colour (Hunter Lab values) and microbiological (total bacterial and yeast/moulds) properties of the parent flours were evaluated. Results indicated that tempering with ozonated water did not significantly alter the chemical, physical and rheological properties of the flours. A statistically significant reduction in the total bacterial and yeast/mould counts were obtained after tempering with ozonated water ($P \leq 0.05$). Results suggest that the water ozonated up to 11.5 mg ozone/l can be successfully used in the tempering of soft and hard wheat without deterioration in the flour quality. © 2001 Elsevier Science Ltd. All rights reserved.

Keywords: Milling and baking parameters; Ozone; Tempering; Wheat flour

1. Introduction

Ozone is one of the agents which has potential applications in the food industry. As an oxidising and sterilising agent, ozone has been used for washing and storage of fruits/vegetables (Hampson, Montevalco, & Williams, 1996; Simons & Sanguansri, 1997; Liangji, 1999; Faitelberg, Bykova, & Orlova, 1979), process water sterilisation and recycling (Bernhat, Schell, & Leusse, 1986; Sheldon & Brown, 1986; Gelzhaeuser, 1985), destruction of pesticides and chemical residues (Beltran, Garcia, & Alvarez, 1999), elimination of undesirable flavours produced by bacteria (Elvidge & Blitz, 1992), control of microorganisms on poultry and meat products (Chen, Chang, & Ing, 1987; Sheldon & Brown, 1986; Yang & Chen, 1979; Kaess & Weidemann, 1973), and production of sterile water for final rinses of bottles, cans, beer fillers and tanks (Ito & Seeger, 1980). Ozone has approximately 1.5 times more oxidising power than chlorine which has got some limitations in practice (limited effect on bacteria on the surface of fruits and vegetables, possible residual by-products) (Liangji, 1999). Commercially, ozone gas is generated from air or pure oxygen using ozone generators. Relatively small

quantities of ozone and short contact times are sufficient for the desired effect on the food product (Tenney, 1973). Since ozone gas decomposes rapidly to diatomic O_2 , it should be generated on the site and used immediately. No long-term/acute effects of ozone on humans has been found (Liangji, 1999). Ozone can be applied to food products as a gas or it can be dissolved in water using certain bubbling techniques.

Limited research has been conducted using ozone on cereals and cereal-based products. Slaughter (1988) conducted field studies to evaluate the response of hard red winter wheat to chronic ozone levels. Results showed that the baking quality of the flours obtained from kernels exposed to ozone was reduced as the concentrations of ozone in the modified atmosphere increased. Similar results were obtained for soft red winter wheat samples (Mulchi, Sammons, & Baenziger, 1986; Rudorff, Mulchi, Fenny, Lee, & Rowland, 1996; Scotti, Silva, & Botteschi, 1994). Fangmeier, Grueters, Hoegy, Vermehren, and Jaeger (1997) showed that the nutrient uptake from fertilisers did not change for spring wheat grown in the modified field atmospheres containing ozone gas. Pleijel, Skarby, Walin, and Sellden (1995) observed that nitrogen content of spring wheat increased linearly with the ozone concentration in the modified field atmosphere. The thiamine content of nama men, a Japanese noodle, decreased when ozone-treated flour was used in the production. There was no

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Notation

BU	Brabender units
FU	Farinograph units

significant change in the concentration of riboflavin in the product. Appearance, odour, taste and texture of nama men were not affected adversely by the use of ozonated flour (Naito, Sawada, & Yamaguchi, 1989).

Tempering (i.e., adding water to grain and allowing the grain to rest for a period of time prior to milling) is applied to wheat kernels to toughen the bran making it resistant to being broken into small pieces during milling and to soften the endosperm making it easier to grind (Hoseney, 1994). The chemical and microbiological quality of the water used for tempering may influence the properties of resulting flour. The ozone gas has been included into GRAS (generally regarded as safe) category by US regulations in 1997 (Liangji, 1999). This regulation brought ozone gas many applications in the food industry. Considering that ozonated water can be used for tempering, the knowledge of the effects of ozonated water used during tempering on the milling and baking properties of the resulting flours would be useful. The purpose of this study was, therefore, to investigate the effect of ozonated water given to soft and hard wheat during tempering on the selected properties of the parent flours.

2. Material and methods

2.1. Wheat samples

Two different wheat varieties were used: Adıyaman Beyaz (AB, a soft white wheat) and Arjantin (A, a hard red wheat). The wheat samples were obtained from commercial millers in Gaziantep, Turkey. These varieties were selected to present strong (A) and weak wheat (AB) used in commercial flour blends for bread making.

2.2. Ozonated water

Ozonated water was obtained with an ozone generator (OPAL, Model OM1, Ankara, Turkey) using atmospheric air. The generator has a capacity of 20 g ozone/h requiring 1 kW power at 220 V and 50 Hz. Ozone gas obtained from the ozone generator was circulated through a 100 l stainless steel tank using a centrifugal circulation pump equipped with a sinter with a pore size of 100 µm to dissolve the ozone gas in the circulating water. The temperature of ozonated water was kept at 20°C by means of a cooling system. The water was ozonated to concentrations of 1.5 and 11.5 mg ozone/l, determined spectrophotometrically at 500 nm

(1.14732.0001 ozone test, Merck KGaA, Germany). It was observed that the ozone was diminished totally in the water after 40 min.

2.3. Tempering

Wheat samples were cleaned from foreign particles and other impurities (stones, foreign seeds, etc.) by hand prior to tempering with distilled and ozonated water. A 500 g of cleaned wheat sample was mixed with tempering water and placed in a closed stainless steel chamber revolving slowly (30 rpm) for 30 min. The wheat was then transferred to tight glass jars and left for 24 h at 20°C. The amount of tempering water was calculated according to the initial moisture content of the wheats (Özkaya & Kahveci, 1990). Soft wheats are tempered to a moisture content of 15.0–15.5% whereas 16.0–16.5% moisture is recommended for hard wheats prior to milling (Hoseney, 1994). The AB sample, a soft wheat, was tempered with 32.0 ml of water so that the moisture content of the wheat would be increased from 11.0% to 15.5% (wet basis). Preliminary experiments showed that some of the water added for tempering is not totally absorbed by the kernels (data not given). Therefore, a 20% excess water was added to compensate the losses. Similarly, 36.0 ml of water was added to sample A, a hard wheat, to increase its moisture content from 11.5% to 16.5% (wet basis).

2.4. Laboratory milling

Tempered AB and A wheat samples were milled on a Brabender Quadrumat Junior Mill (Brabender OHG, Duisburg, Germany) to white flour. All flours were mixed well and stored in tight jars at 5°C. Extraction rate (g white flour obtained/100 g cleaned wheat) for each tempered wheat sample was measured using an analytical balance (Sartorius GmbH, Goettingen, Germany).

2.5. Chemical and physical analysis

Protein (N × 5.7), ash, and moisture contents were determined according to AACC Approved Methods 46-12, 08-01, and 44-15A, respectively (Anon., 1995). The Zeleny sedimentation test was carried out according to the method of the International Association of Cereal Chemists (IACC) (Anon., 1972). Falling number values were determined according to the IACC method (Anon., 1960) with a type 1500 Falling Number apparatus (Falling Number, Huddinge, Sweden).

2.6. Rheological analysis of the dough

Measurements of water absorption, dough development time, dough stability, degree of softening and farinograph quality number (Anon., 1972) were carried

out on a Brabender farinograph (model 8 101, Brabender OHG, Duisburg, Germany). Extensibility, maximum resistance to extension, energy and ratio number of the dough (Anon., 1960) were determined using a Brabender extensograph (model 8 600, Brabender OHG, Duisburg, Germany). Dough extension curves were obtained after 45, 90, and 135 min of dough proofing. The test result after 135 min was used for evaluation.

2.7. Microbial analysis

Microbial analyses were carried out aseptically by mixing 1.0 g kernel with 20.0 ml sterile phosphate buffer (pH 7.0) using a Stomacher blender (Stomacher 400). Serial dilutions from 10^{-1} to 10^{-3} levels were made. Pour plate technique was used for total bacterial count (plate count agar) while surface spread method was used for yeast and moulds (malt extract agar). The plates were incubated at 25.0°C for 5 days. The plates having less than 300 cfu (colony forming unit) were counted. The results were expressed as log cfu/g dry weight. Both pour and spread plates were carried out in triplicate for each dilution.

2.8. Colour analysis

Colour of flours was measured using a Hunter Lab colorimeter (model ColorQUEST II, Virginia, USA). The instrument was calibrated against a standard white tile (No. C2-22326, $L = 91.9$, $a = -1.4$, and $b = 2.0$) where L indicates lightness, $-a$ to $+a$ indicates green–red, and $-b$ to $+b$ indicates blue–yellow. All measurements were replicated twice.

2.9. Statistical analysis

The data were statistically analysed by analysis of variance (ANOVA) using Statgraphics (Anon., 1991).

The least significant differences (LSD) were calculated with the same software.

3. Results and discussion

The rate of extraction strongly depends on the adherence of the outer layers of the kernel (i.e., bran) to the starchy endosperm. Results show that ozone treatment did not alter the milling efficiency of both soft (AB) and hard wheat (A) giving similar rate of extraction (Table 1). It can be assumed that ozone did not modify the interaction of components of the kernels regarding the extraction rate. Falling number is an indication of α -amylase activity in flour (Köksel, Sivri, Özboy, Başman, & Karacan, 2000). The deficiency of α -amylase in flour can result in problems in the crumb and crust of the breads produced (Hoseney, 1994). Results shown that ozone did not effect the α -amylase activity of the flours adversely. The suitability of flours used in bread-making can be assessed using sedimentation volumes, the higher the volume of the suspended flour particles, the better the quality of the flour (Köksel et al., 2000). Any degradation or side reaction of the proteins in the flour may result in reduced sedimentation volumes with decrease in flour quality (Hoseney, 1994). Results indicate that (Table 1) ozone treatment did not cause any chemical or physical changes leading to changes in sedimentation volumes. On the colour of the flours, ozone in gas or aqueous form has the ability to decolourise some food components by oxidising the pigments (Chen, Chiu, & Huang, 1997). Commercially produced cake flours can be oxidised using chlorine gas to whiten the flours and to improve the starch gelatinization properties (Hoseney, 1994). The colour of flour can be measured using CIE colour systems (Commission Internationale de L'Eclairage) (Oliver, Blakeney, & Allen, 1992). In this system L values describes the lightness

Table 1

Chemical and physical properties of the flours produced with the Brabender Quadrumat Junior Mill from Adıyaman Beyaz (AB) and Arjantin (A) tempered using water (W) and ozonated water (OW1: 1.5 mg ozone/l, OW2: 11.5 mg ozone/l)^{A, B}

Property	AB-W	AB-OW1	AB-OW2	A-W	A-OW1	A-OW2
Extraction rate (% of total weight)	64.5a	65.3a	63.2a	55.2b	54.8b	53.9b
Water content (%)	14.9a	15.0a	14.8a	16.5b	16.3b	16.2b
Protein ^A (% N \times 5.7)	10.9a	10.7a	10.8a	12.2b	12.4b	12.2b
Falling number (s)	213a	220a	209a	275b	269b	276b
Zeleny sed. vol. (ml)	31a	30a	28a	31b	33b	33b
Ash content ^A (%)	0.7a	0.6a	0.6a	0.5a	0.6a	0.5a
Hunter						
L	95.2a	94.5a	95.5a	90.1b	91.1b	91.5b
a	1.2a	1.5a	1.4a	0.9b	1.1b	1.0b
b	5.6a	5.2a	5.4a	7.2b	7.3b	7.5b

^A Dry basis.

^B The same letter within a row are not significantly different ($P \leq 0.05$) by LSD.

(bran content) while *b* values correlates well with the pigmentation (yellowness) of the flours (Alfin & Çakmakli, 1999). It appears from the results of this study that the ozone treatment applied during tempering was not sufficient in terms of ozone concentration and contact time to oxidise the pigments in the wheat giving similar values of *b* values for flours tempered with ozonated water (Table 1).

The farinograph and extensograph results of wheats tempered with water show the characteristics of weak and strong flour for bread-making. Sample AB-W shows low stability and high degree of softening (i.e., weak flour) (Table 2) while sample A-W gives high stability and low degree of softening (i.e., strong flour) (Table 2). Similarly, the extensograph results of AB-W and A-W verifies the characteristics of a weak (low energy and low resistance) and strong flours (high energy and high resistance), respectively (Table 3).

Farinograms have been used in milling and baking industries to evaluate the dough properties of the flours to be used in bread making. The results given in Table 2 shows that ozone treatment did not significantly change the farinograph results of the soft and hard wheat samples. Formation of new disulphide bonds in the presence of an oxidizing agent would increase the strength of the dough with high stability and low degree of softening (Hoseney, 1994). Similarly, any cleavage of the disulphide bonds would result in the weakness of the

dough giving low stability and high degree of softening (Ainsworth, 1994). Since ozone has an oxidising nature, one would expect the formation of new disulphide bonds due to the oxidising effect. Results show that (Table 2) this was not even the case in soft wheat sample tempered with ozonated water with a ozone concentration of 11.5 mg/l (AB-OW2), where the penetration of ozonated water would be easier than in the hard wheat (A). Considering that half-life of ozone in water is less than 20 min (Liangji, 1999), it can be assumed that the contact time was not sufficient for such an oxidising effect.

Oxidising agents are used to improve the bread-making capacity of flour. The use of oxidants such as acetone peroxide and chlorine dioxide (Hoseney, 1994) would decrease the extensibility of the doughs while maximum resistance and energy values would be increased giving the dough more strength at the expense of extensibility. As mentioned above, ozone is an oxidising agent and the results show that (Table 3) tempering with ozonated water did not alter the extensograph results of the flours suggesting no net oxidising effect of ozone on the wheat kernels during tempering..

Microbiological analysis showed that tempering the kernels with ozonated water reduced the total and yeast/mould counts which are statistically lower than that of untreated control samples at 95% confidence interval (Table 4). The number of micro-organisms was reduced

Table 2

Farinograph results of doughs from Adıyaman Beyaz (AB) and Arjantin (A) tempered with water (W) and ozonated water (OW1: 1.5 mg ozone/l, OW2: 11.5 mg ozone/l)^A

	AB-W	AB-OW1	AB-OW2	A-W	A-OW1	A-OW2
Water absorption (%)	59.5a	59.6a	60.2a	62.6b	62.8b	63.1b
Development time (min)	1.5a	1.5a	1.4a	1.8b	1.7b	1.8b
Stability (min)	2.9a	3.0a	3.1a	6.1b	6.0b	6.2b
Degree of softening (12 min after max., FU)	135a	132a	137a	94b	97b	95b
Farinograph quality number	34a	39a	35a	62b	58b	61b

^A The same letter within a row are not significantly different ($P \leq 0.05$) by LSD.

Table 3

Extensograph results of doughs from Adıyaman Beyaz (AB) and Arjantin (A) tempered with water (W) and ozonated water (OW1: 1.5 mg ozone/l, OW2: 11.5 mg ozone/l)^{A, B}

	AB-W	AB-OW1	AB-OW2	A-W	A-OW1	A-OW2
Extensibility (mm)	134a	132a	135a	151b	154b	155b
Max. resistance to extension (BU)	134a	138a	135a	413b	409b	400b
Energy (cm ²)	25a	23a	24a	80b	81b	80b
Ratio number	0.9a	0.9a	0.8a	1.8b	1.8b	1.8b

^A The same letter within a row are not significantly different ($P \leq 0.05$) by LSD.

^B Test results after 135 min of proofing.

Table 4

Total bacteria (TB) and mould/yeast counts (MY) of Adıyaman Beyaz (AB) and Arjantin (A) tempered with water (W) and ozonated water (OW1: 1.5 mg ozone/l, OW2: 11.5 mg ozone/l) (log cfu/g dry weight)^{A,B}

	AB-C	AB-W	AB-OW1	AB-OW2	A-C	A-W	A-OW1	A-OW2
TB	4.6a	4.0b	3.4c	2.5d	5.5e	5.1f	4.7g	4.0h
MY	3.5a	3.3b	3.0c	2.4d	4.1e	4.0f	3.7g	3.1h

^AC is the non-tempered control sample.

^BThe same letter within a row are not significantly different ($P \leq 0.05$) by LSD.

as the ozone concentration in tempering water was increased from 1.5 to 11.5 mg/l (Table 4). The microbial population of wheat kernels before milling is important for the final microbial quality of the resulting flours. Flours with a high number of micro-organisms reduce the storage life of the flours and cause a reduction in the overall quality of the flours. Therefore, it is preferable to have flours with a low number of micro-organisms. The results suggest that ozonated water can be successfully used for wheat tempering for the reduction of microbial populations. Considering that ozone is approximately 30,000 times more effective on *Escherichia coli* than chlorine (Kim, Youssef, & Dave, 1999), ozone can be an alternative for chlorine or other disinfectants used in processing water.

3.1. Conclusion

The use of ozonated water in tempering of wheat did not change the chemical and physical properties of the parent flours regarding the baking and milling parameters. A statistically significant reduction in the total bacteria and yeast/mould populations in the wheat kernels tempered using ozonated water was observed ($P \leq 0.05$). It can be concluded that ozonated water up to a concentration of 11.5 mg/l can be successfully used in the tempering of soft and hard wheat without any reduction in milling and baking quality of the parent flours.

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