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EFFECT OF MODIFIED ATMOSPHERE PACKAGING ON STABILITY OF THREE KINDS OF BREAD

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Abstract

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The study evaluates effect of ordinary and modified atmosphere N_2 and CO_2 on bread packaging and changes of selected bread parameters, moisture content (MC) and water activity (Aw), in real storage time. MC has a significant influence on physical properties of bread and Aw characterizes its microbiological stability. Both parameters are functionally dependent. Manometric method was used for measurement of Aw and gravimetric method was used for measurement of MC. Samples of three kinds of bread, gluten-free, Šumava bread, and Bavorský bread, packaged into barrier wrappers, were stored at the room temperature of 20 °C. MC and Aw were measured in real storage time in intervals of three days for all kinds of bread, always in crust and crumb separately. Individual measurements were finished when a mould were discovered in samples. The initial MC of crust was in the range of 21.01–29.26% MC (w.b.) and the final MC in the range of 26.79–33.58% MC (w.b.) in tested breads. MC of crumb was in the range of 34.49–46.58% MC (w.b.) at the beginning and in the range of 32.92–44.21% MC (w.b.) at the end in tested samples. Minimum differences within values of MC showed gluten-free bread during storage time. Values of Aw were in the range of 0.863–0.948 at the beginning and in the range of 0.933–0.958 at the end of measurement in crust, for all samples. Values of Aw were in the range of 0.960–0.961 at the beginning and in the range of 0.952–0.961 at the end of measurement in crumb. Minimum differences within values of Aw showed gluten-free bread again. The highest shelf-life has been achieved in CO_2 atmosphere, for all kinds of bread. Mathematical models with ability for MC and Aw prediction in real time of storage were created for Šumava bread.

water activity, dry matter, moisture, manometric method, carbon dioxide atmosphere, nitrogen atmosphere

Today, the emphasis is given to a prolonging the shelf-life of food. For some food it can be obtained with some operations such as pasteurization or sterilization. However, these methods are inappropriate for bakery products. Bread is classified as a food with a short shelf-life (Fik, 2004). In addition, bread is material composed of two structures: from harder, drier crust with lower Aw and higher dry matter. This layer forms the primary barrier protecting the inner, moist crumb (Altamirano-Fortoul *et al.*, 2013). Boundary shifting of shelf-life is more important for these products. The current research topics increase the shelf-life of product by use of expensive procedures of focused microwaves. For prolonging the shelf-life is used method of packaging in modified atmosphere as further utilized and investigated method. Modified atmosphere packaging (MAP) application prolongs the shelf-life of product on three ways. Chemically, it controls biochemical processes of degradation and decrease the oxidation. Microbiologically, it prolongs shelf-life by suppressing the growth of bacteria and moulds. Physically, it reduces loss of MC (Smith, 1993) and stabilizes the value of Aw (Kotsianis *et al.*, 2002). The use of higher concentrations of CO_2 above 20% shows significant bacteriostatic and fungistatic properties and prevents the growth of aerobic microorganisms commonly found in bread (Muizniece-Brasava *et al.*, 2012). Bread is usually packed in an atmosphere composed of a mixture of gases, 60-80% CO_2 and 20-40% N_2 (Fik *et al.*, 2012). Also hygiene of raw materials and working environment is very important as well as the quality of modern technology and adequate temperature of processing (Patel *et al.*, 2005).

Aw determines the availability of water for growth of microorganisms (Tang, 2005). The critical value is 0.6. The value of Aw of bread ranged from 0.971 to 0.976 in crumbs and above 0.822 in crust, depending on storage time and age of bread and environmental conditions (Castro-Prada *et al.*, 2009; Altamirano-Fortoul and Rosell, 2010). Bread is a suitable substrate for the growth of microorganisms and moulds due to the high Aw and its composition. These attach and reproduce easily on uneven surface (Enkhjargal *et al.*, 2012).

Another factor that potentially influences bread properties is humidity. In conventional baking process, temperature and time have direct relationship with the crust color and MC. High humidity application as reported by Xue and Walker (2003) has affected the final quality of baked product by enlighten the crust color, increasing volume of product and final MC. Most of the researches that incorporate humidity during baking mainly focus on the properties of product directly after baking. However, the effect of baking with humidity on product during storage prior to the shelf-life study is not extensively evaluated yet (Muhamad, 2007).

MC significantly affects properties of gluten in bakery products, too. Gluten is non-pure protein system. Rheological properties of gluten follow of characteristics and interactions among proteins although non-protein components have significant effects. Gluten proteins comprise two main sub-fractions, glutenins that confer strength and elasticity and gliadins that impair the viscous properties on the gluten dough (Rosell and Foegeding, 2007). Rheological properties of gluten are not fully explored yet. Gliadin behaves like a viscous liquid and glutenin as a coherent, flexible, firmness substance also after mixing with water. Differences in mixing properties among wheat flour doughs are probably related to the quantity as well as to the quality of glutenin. Gluten content is given in accordance with the flour used in bread. There are various kinds of wheat with different gluten content as well as bakery products where wheat flour is replaced with other type of flour (Janssen *et al.*, 1996). These substitutions are used mainly because of allergic reactions in some parts of population.

The fundamental objective of this study was to evaluate the effect of ordinary atmosphere packaging and MAP with 100% N_2 and 100% CO_2 on shelf life of gluten-free bread, Šumava bread (wheat-rye), and Bavorský bread (dark, rye-spelled-malt) and to compare the ability of these atmospheres from viewpoint extending shelf-life of bakery product tested. Another objective was to measure and to analyse selected qualitative parameters moisture content (MC) and water activity (Aw) of samples tested in real time of storage in connection with the fundamental objective. The final related objective of the study was mathematical analyse of selected data measured and mathematical model creation for functional dependence of MC and Aw on time with basic statistical evaluation.

MATERIALS AND METHODS

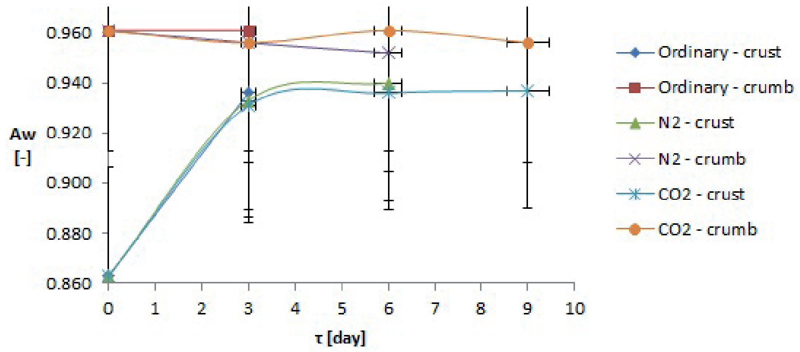
Three kinds of commercially available bread, gluten-free, Šumava bread (light, wheat-rye), and Bavorský bread (dark, rye-spelled-malt with seeds) were chosen as samples. These samples were cut into slices under sterile conditions in the laboratory and placed into prepared wrappers. Initial values of Aw and MC were determined for each kind of bread. Samples were packaged using ordinary atmosphere, carbon dioxide atmosphere (CO_2), and nitrogen atmosphere (N_2). Samples were stored at 20 °C in a shady place and monitored. Every three days was removed one set of samples (from each atmosphere each a slice) and sensory evaluated occurrence of mould. Each test was terminated when it has mold. Samples were opened and Aw and MC were measured in crust and crumb separately in the case of absence of visible occurrence of mould. Manometric method was used for measurement of Aw. MC was determined using gravimetric method. The halogen dryer was used for this purpose. A mathematical model of Aw and MC course in real time of storage was created for crust and crumb in Maple program for the most sold Šumava bread in the atmosphere with the longest shelf-life of food based on the obtained results.

RESULTS AND DISCUSSION

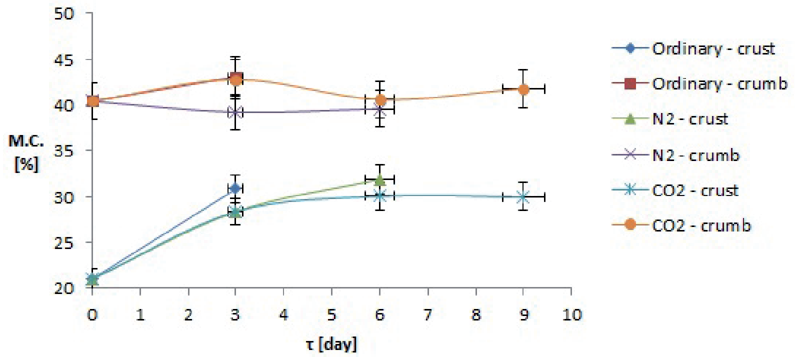
Data measured of bread MC and Aw in real time of storage are presented in Figs. 1–6. In general, MC of crumb is higher than MC of crust for all samples tested. Differences between MC crumb and MC crust are maximal at the beginning of the measurements except for the gluten-free bread. Course of Aw corresponds to the course of MC. A decrease of MC causes decrease of Aw and vice versa. These results are consistent with the theoretical hypothesis and with literature sources, too, for example Rasmussen and Hansen (2001).

Behaviour of the gluten-free bread was completely different from viewpoint of MC and Aw courses, if compare with other samples tested, see Figs. 5 and 6. Values both of Aw and MC have minimal changed during the storage time for all atmosphere used. These results show that structure of gluten-free bakery is less hygroscopic than common bakery products (Janssen *et al.*, 1996).

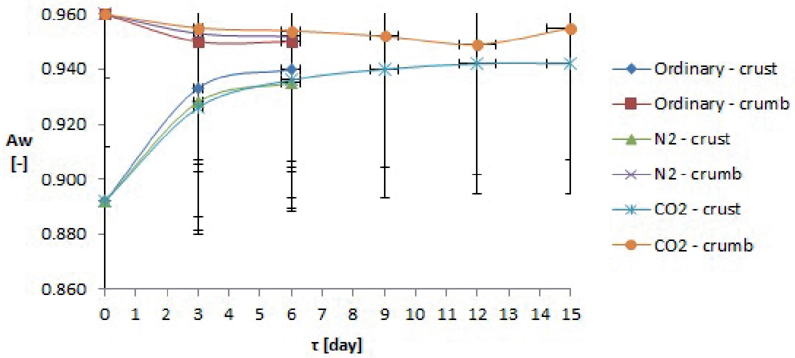
Aw and MC values of bread samples before visible moulds spoilage are listed in Tab. I.



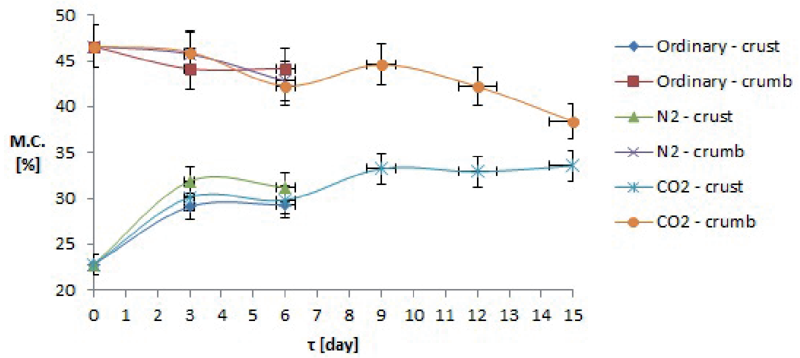
1: *Effect of varying atmospheres on the Aw of the Bavorský bread during storage time*



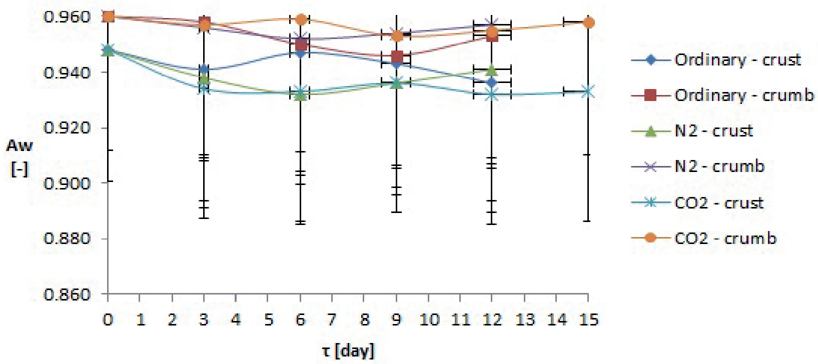
2: *Effect of varying atmospheres on MC of the Bavorský bread during storage time*



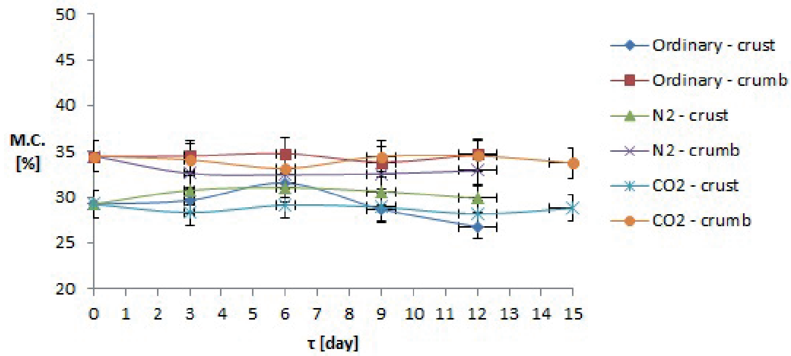
3: *Effect of varying atmospheres on the Aw of the Šumava bread during storage time*



4: *Effect of varying atmospheres on MC of the Šumava bread during storage time*



5: *Effect of the varying atmospheres on the Aw of gluten-free bread*



6: *Effect of varying atmospheres on the MC of the gluten-free bread*

I: *Aw and MC values of samples tested before visible moulds spoilage*

		First day		C. day*–ordin. atm.		C. day*–N_2 atm.		C. day*–CO_2	
Bread		**Aw[-]**	**M.C.[%]**	**Aw[-]**	**M.C.[%]**	**Aw[-]**	**M.C.[%]**	**Aw[-]**	**M.C.[%]**
Gluten-free	crust	0.948	29.26	0.936	26.79	0.941	29.88	0.933**	28.82**
	crumb	0.960	34.49	0.953	34.67	0.957	32.92	0.958**	33.73**
Šumava	crust	0.892	22.82	0.940	29.31	0.935	31.22	0.942**	33.58**
	crumb	0.960	46.85	0.950	44.21	0.952	42.80	0.955**	38.43**
Bavorský	crust	0.863	21.01	0.936	30.83	0.940	31.89	0.937	29.98
	crumb	0.961	40.40	0.961	43.07	0.952	39.60	0.956	41.80

*Critical day, i.e. a day of last measurement carried out before visible moulds on samples
**Values at the end of measurement without visible development of moulds

Prevention to the mould development has a significant effect on prolongation the shelf-life of bread. The carbon dioxide atmosphere appears to be the most reliable in this regard, as reported Fik *et al.* (2012). Above presented results of MAP tests confirmed this fact. The carbon dioxide atmosphere is able to suppress the development of moulds for more than the 15 days for Šumava bread and gluten-free bread. The gluten-free bread was maintained for the longest time, 12 days, in non CO_2 atmospheres. Bavorský bread showed the worst results in storage due to seeds as highly contaminants. Occurrence of moulds was visible after three days storage in ordinary atmosphere, after 6 days in nitrogen atmosphere and after nine days in carbon dioxide atmosphere.

Thus, it is recommended to store bread only very short time to maintain the stability from viewpoint of Aw and MC of crust and crumb. However, it is suitable to use bread made from gluten-free flour without seeds and to choose carbon dioxide atmosphere for longer storage time. Use of non-contaminant raw material (Rosenkvist and Hansen, 1995) or prevention of secondary contamination by good hygiene practice and observance of correct temperatures during production are important to reduce risk for processing with seeds (Patel *et al.*, 2005). Use of moisture absorbers is another way to prolong shelf-life of bakery products, e.g. Salminen *et al.*, 1998. However, they would be dehydrated product too and this product would be then inedible.

II: *Mathematical model for dependence of Aw on storage time* $\underline{\tau}$ *of Šumava bread wrapped in* CO_2 *atmosphere at 20 °C*

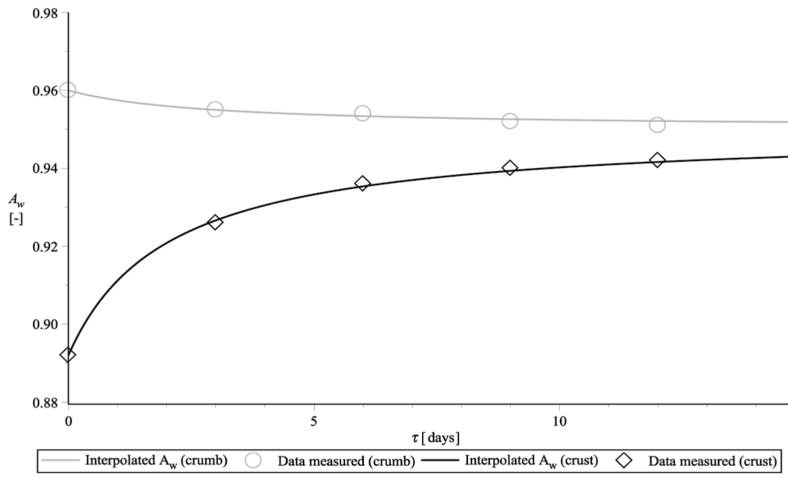
	Model	R^2
Crust	$Aw = \frac{-16723.14 \times \tau - 31727.31}{-17603 \times \tau - 35570.61}$	0.999
Crumb	$Aw = \frac{-48477.33 \times \tau - 1.37 \times 10^5}{-51012.23 \times \tau - 1.42 \times 10^5}$	0.999

III: *Mathematical model for dependence of MC on storage time* $\underline{\tau}$ *of Šumava bread wrapped in* CO_2 *atmosphere at 20 °C*

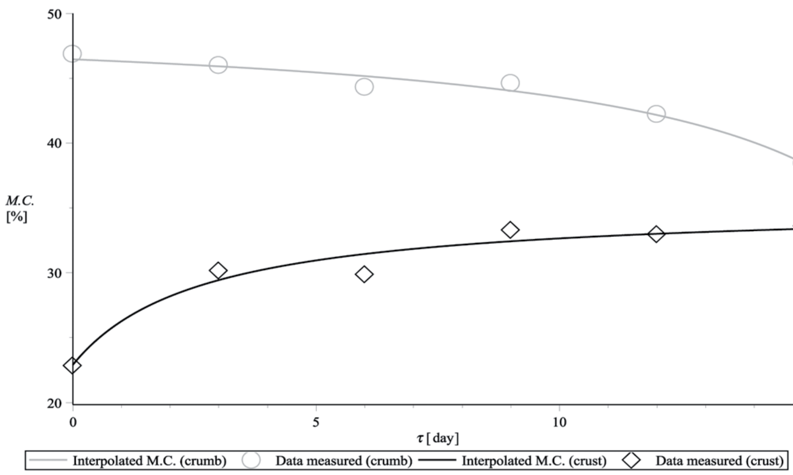
	Model	R^2
Crust	$MC(w.b.) = \frac{2 \times 10^{-5} \times \tau + 4 \times 10^{-5}}{5.74 \times 10^7 \times \tau + 1 \times 10^{-5}}$	0.995
Crumb	$MC(w.b.) = \frac{2 \times 10^{-5} \times \tau + 4.5 \times 10^{-5}}{-4.61 \times 10^7 \times \tau + 1 \times 10^{-5}}$	0.988

Mathematical models describing course of Aw and MC in real time were created using Maple software for Šumava bread as the most sold bread in carbon dioxide atmosphere. The mathematical equations were generated based on data measured, see Tab. II and III. These models were developed both for crust and crumb and can be used for Aw and MC prediction in dependence on required storage time $\underline{\tau}$ at common room temperature 20 °C. There is presented responsible coefficient of determination R^2 in these tables, too.

Samples of Šumava bread had the highest resistance to development of moulds in the CO_2 atmosphere and there was also clearly visible convergence of MC and Aw between crust and crumb. Balancing MC and Aw between the crust and crumb occurs when a sample of bread is stored for extended periods. Crust loses its barrier properties during storage time because these properties depend mainly on MC.



7: *Relation between Aw and time in Šumava bread stored in* CO_2 *atmosphere at 20 °C*



8: *Relation between MC and time in Šumava bread stored in a* CO_2 *atmosphere at 20 °C*

CONCLUSIONS

Realized measurements showed dependency between MC and Aw in real time of storage for all kinds of tested breads. The methodology used is appropriate. Convergence of MC and Aw between crust and crumb is visible during storage time. The moisture transfer from crumb into the crust results in Aw increase. The initial MC of bread crust was in the range of 21.01–29.26% MC (w.b.) and the final MC in the range of 26.79–33.58% MC (w.b.). MC of bread crumb was in the range of 34.49–46.58% MC (w.b.) at the beginning and in the range of 32.92–44.21% MC (w.b.) at the tests. In general, MC of crumb is higher than MC of crust for all samples tested. Differences between crumb MC and crust MC were maximal at the beginning of the measurements except for the gluten-free bread. Measurements carried out under laboratory conditions confirmed that the carbon dioxide creates the most reliable atmosphere for shelf life extending of breads.

SUMMARY

Modified atmosphere has a significant effect on the prolongation of shelf-life of bread. Carbon dioxide atmosphere prevents the development of moulds better than ordinary or nitrogen atmosphere. This atmosphere can extend the shelf-life of gluten-free bread and wheat-rye bread for more than 15 days at 20 °C. Packaging of bread with seeds is problematic. Such bread is perishable already after nine days of storing. Aw was the highest at the beginning of storing in gluten-free bread, 0.948, in crust. Then Aw ranged from 0.932 to 0.947. The initial values of Aw in crust were 0.892 and 0.863, respectively for wheat-rye bread and dark bread. Aw rapid increased in the first three days of storage and then Aw remained in the range of 0.926–0.942 for wheat-rye bread and 0.931–0.940 for Bavorský bread. Aw of crumb was more stable. The initial Aw of gluten-free was 0.960 and then Aw ranged of 0.958 to 0.946. The initial Aw of Bavorský bread was 0.960 and then ranged from 0.961 to 0.952 in crumb. The initial Aw of wheat-rye bread was 0.960 and then slightly decreased during storage in the range of 0.955–0.949 in crumb. Manometric method was used for measuring of Aw. MC was most constant in gluten-free bread. The initial value of MC was 29.26% and then ranged from 31.56% to 26.79% during storage in crust. The initial value of MC was 34.49% and then ranged from 34.79% to 32.46% in crumb. MC of Bavorský bread was 21.01% in crust. MC was increased significant a after that stabilized in the range from 31.89% to 28.37% for all types of atmosphere during the first three days of storage. The initial value of MC was 40.40% in crumb and then decreased to the values 39.60–39.22%, only for nitrogen atmosphere. The initial value of MC of wheat-rye bread was 22.82% in crust and after that increased rapid during the first three days. Then MC remained in the range from 33.58% to 29.11%. The initial MC was 46.58% in crumb and then increased to the values in the range from 49.98 to 38.43%. The convergence of MC between crumb and crust is visible on 15th day of storage. MC of crust was 33.58% and MC of crumb was 38.43% on this day. It can be predict equalization of Aw and MC between crust and crumb in Šumava bread packaged in carbon dioxide atmosphere, based on mathematical model created in Maple program.

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