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BROWNING DEVELOPMENT IN BAKERY PRODUCTS ENRICHED WITH FOOD INDUSTRY BY-PRODUCTS

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ABSTRACT

During baking, the formation of colour is due to the Maillard reaction, and caramelization of sugars. The formation of colour in bakery products during baking is widely known as browning. As well as baking, the development of browning in bakery products is a simultaneous heat and mass transfer process that occurs mostly in a non-ideal system under non-ideal conditions. Besides the major influence of this phenomenon on the initial acceptance of products by consumers, it is the responsible for other relevant changes occurring in food during baking, i.e. production of flavour and aroma compounds, formation of toxic products (e.g. acrylamide), and decrease of nutritional value of proteins. The present work investigates the effect of some dietary fibers from different origins (apple pomace (AP), brewers' spent grain (BSG)) on the bread crust and crumb colour changes during baking. AP, as inexpensive and primary by- product of apple juice and cider production, is a good source of dietary fibers, polyphenols and pectin. BSG is the major by-product of the brewing industry and a good source of protein, cellulose, noncellulosic polysaccharides, chiefly arabinoxylans and lignin.

Because of that, the aim of this study was to investigate the effect of AP and BSG addition (5, 10 and 15 %) on bread crust and crumb colour. Colour was measured using a colorimeter. Lightness, redness and yellowness of bread samples fortified with different percentages of BSG were measured as L^*, a^* and b^* value respectively. The change in dark colour was due to the incorporation of AP and BSG. L^* value decreased with the increase of addition of AP and BSG. In contrast a* and b* values increased with increasing AP and BSG addition respectively. Colour measurement data indicated that samples with addition dietary fibers (AP and BSG) were darker. Total colour change (ΔE) and browning index (BI) increased proportionally to dietary fibers addition, with more pronounced change in samples with AP addition.

Keywords: bread, non-enzymatic browning, colour, apple pomace, brewers' spent grain

INTRODUCTION

Dietary fiber (DF) as a class of compounds includes a mixture of plant carbohydrate polymers, both oligosaccharides and polysaccharides, e.g., cellulose, hemicelluloses, pectic substances, gums, resistant starch, inulin, that may be associated with lignin and other non-carbohydrate components (e.g., polyphenols, waxes, saponins, cutin, phytates, resistant protein) [Lattimer & Haub, 2010; Stear, 1990]. Baked food products are well liked by consumers all over the world. Because of their high consumption, they can potentially be used as carriers of DF. Different plant fiber products are added to various baked food products in order to increase their fiber content. DF is currently considered as a critical ingredient in food products such as baked goods, beverages, meat, confectionery, dairy and pasta. Most frequently, DF are incorporated into bakery products to prolong freshness due to their capacity to retain water. The research and development efforts on value addition and efficient utilization of nutritionally rich agro-industrial residues such as whey, sugar beet pulp, cassava bagasse, apple pomace, citrus waste, coffee pulp/husk, etc. are gaining momentum around the world.

Apple (Malus domestica Borkh.) is probably the oldest fruit known to man and is favoured by millions of people around the globe. In large-scale apple processing industries, the wastes can be categorized into two types. The first type is the fruit discarded into the sorting belt due to its partially bruised/spoiled nature and named as belt rejection. The second type is the apple pomace (AP) obtained after juice extraction. AP is a left-over solid residue (25 – 30 % of the total processed fruits) obtained after the extraction of apple juice. AP is also used for extraction of DF, xyloglucan, natural antioxidant and aromatic compounds. The apple fruit is highly nutritious and contains carbohydrates, proteins, minerals and natural antioxidants. A number of fiber enriched bakery products were prepared by adding dried AP powder on a wheat flour replacement basis. A chemical analysis of the finished product showed that the bakery products prepared by adding apple fibers had a higher dietary fiber content than other sources. Currently, the primary usage of apple pomace is livestock feed. Some efforts have been made for increasing the value added usage of apple pomace, such as producing pectin and adding in different types of bakery products. Apple pomace flour (APF) or wet apple pomace (WAP) can partially substitute wheat flour or meat in bakery or meat products, respectively to enhance dietary fiber and bioactive compounds in the products. This innovative approach to create functional food items could not only increase the value of the by-product from apple juice processing, but also allows commonly consumed products with enhanced health benefits [Sudha, Baskaran & Leelavathi, 2007].

Brewers' spent grain (BSG) is the major by-product of the brewing industry, representing around 85 % of the total by-products. BSG is a cheap source of total dietary fiber that could be used as a functional ingredient in different food products and has great potential to be used as a functional ingredient that may provide beneficial effects on human health. BSG is a good source of protein and has been reported to contain about 17 % cellulose, 28 % noncellulosic polysaccharides, chiefly arabinoxylans and 28 % lignin. Because of the relatively low cost and high nutritional value, BSG has been used in the production of flakes, whole wheat bread, biscuits and aperitif snacks. Although the flour prepared from BSG has been successfully incorporated into a number of bakery products. By incorporating BSG up to 15 % in bread-making technology, the level of dietary fiber will increase up to fivefold. Loaf volume, texture, sensory characteristics and shelf life of BSG can be improved using appropriate enzymes and forming sourdough. There are still some limitations in the application of BSG as food additives or as a replacement of the present flours, such as its dark colour and flavour. To control the changes in the favour and physical properties (e.g., texture) of the final products, only relatively small quantities (5 ~ 15 %) of BSG can be incorporated [Mussatto *et al*, 2006].

The present work investigates the effect of some DF from different origins (apple pomace, brewers' spent grain) on the bread colour (crust and crumb) during baking.

MATERIALS AND METHODS

Bread sample preparation and baking

Three different amounts (5, 10 and 15 %) of AP and BSG were incorporated in the bread based on our preliminary studies by considering the minimal impact on the appearance, colour and texture of the products. Baking was carried out in a convection electric oven at 210 °C during 7, 14 and 21 min.

Colour

Surface browning of bread crust samples was measured using colorimeter (Minolta, Model CR-400, Konica Minolta Holdings Tokyo, Japan) and expressed as colour difference Δ*E* and browning indeks (BI) between the raw dough and the samples subjected to heating according to the following equation.

$$\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2} \quad (1)$$

where: Δ*L* = brightness difference; Δ*a* = redness difference; Δ*b* = yellowness difference

$$BI = \frac{100\cdot(x-0.31)}{0.17} \quad (2)$$

$$x = \frac{a_t + 1.75\cdot L_t}{5.645\cdot L_t + a_0 - 3.012\cdot b_t} \quad (3)$$

Where a_0 is the initial colour measurement of raw bread of the dough of the crust and L_t, a_t and b_t are the colour measurements at the specific baking time.

Results were expressed in the CIE*Lab* colour space and were obtained using the D65 standard illuminant and the 2° standard observer (CIE 1931). The L^* value gives a measure of the lightness of the product colour from 100 for perfect white to 0 for black. The redness/greenness and yellowness/blueness are denoted by a^* and b^* values, respectively. Colorimeter should be calibrated using white boards before measurement. Five replications were performed for each experiment. Averaged results are presented.

RESULTS AND DISCUSSION

The effect of fiber addition (AP and BSG) on the bread colour is summarised in Tables 1- 2 and Figures 1 - 8. Lightness, redness and yellowness of bread samples fortified with different percentages of AP and BSG were measured as L^*, a^* and b^* value respectively (Tables 1 and 2). Significant differences between the crust and crumb of the control bread and the bread obtained with enriched dough were observed.

In terms of crust colour, the control bread gave higher L^* values compared to the breads enriched with fibers from AP and BSG. L^* value decreased with the increase of AP and BSG (83.86 in control to 67.51 and 74.04 in bread prepared with the addition of fibers from AP and BSG). In contrast a^* and b^* values increased with increasing AP and BSG content (Tables 1 and 2). This is mainly due to Maillard and caramelization reactions. A darker color is a characteristic of the Maillard reaction, which was attributed to the degree of polymerization and the presence of low molecular weight sugars in the formulation and the level of its contribution in the recipe [Juszczak *et al*., 2012; Peressini & Sensidoni, 2009]. In crumb colour values, L^* values decrease and changed from white to black when AP and BSG fibres addition level increase. This crumb lightness reduction could be related to the effect of this fibers source on crumb moisture content (greater moisture, lower lightness). Moreover, the increase in level of fibers added increased crumb a^* values of breads enriched by fibers from AP and BSG and b^* values for breads enriched by fibers from AP. As for breads enriched by fibers from BSG, there was no significant difference for the b^* values.

The largest colour change (ΔE) of AP fortified breads in comparison with BSG fortified breads and non-fortified one was found in 15 % AP fortification (Figure 1 - 4). These colour changes could be due to one or both of the following reasons. First, the original colour (light brown) of AP was much darker than that of wheat flour, which could translate into a darker brown colour in the final baked product. Secondly, apple pomace had higher level of sugar compared with wheat flour, allowing for the increased caramelization and Maillard reaction during baking. Maillard reaction, a nonenzymatic browning reaction between amino acids and reducing sugars is the primary colour formation reaction. BSG caused an increase in the amount of amino acid in the bread samples. Thus, the Maillard browning reaction occurred easily with the increase of BSG leading to a decrease of L^* value and increase of a^* value.

Table 1. Colour measurement data (CIE*Lab*) of bread ***crust*** fortified with different percentages of apple pomace (AP) or brewers' spent grain (BSG) and from control samples (those without AP or BSG)

Level of DF substitution	Baking time [min]	*L**	*a**	*b**
control	0	83.86	-1.13	19.68
	7	79.11	-0.83	22.26
	14	72.57	4.16	33.66
	21	65.51	10.07	37.73
5 % BSG	0	74.04	1.99	15.49
	7	67.14	3.14	17.59
	14	66.95	3.53	20.27
	21	65.09	4.38	22.78
10 % BSG	0	70.09	2.93	15.88
	7	71.22	3.07	21.49
	14	59.50	6.30	22.53
	21	56.48	6.47	25.00
15 % BSG	0	68.11	3.61	16.21
	7	59.79	4.63	19.45
	14	65.60	7.82	28.62
	21	61.11	10.59	30.17
5 % AP	0	67.51	5.38	22.96
	7	54.89	11.34	24.87
	14	51.38	12.10	25.10
	21	49.83	12.19	27.47
10 % AP	0	64.65	6.13	18.31
	7	47.47	11.13	18.59
	14	44.61	11.78	22.52
	21	44.05	12.49	25.23
15 % AP	0	60.64	7.84	9.44
	7	40.96	8.18	10.80
	14	38.22	8.91	15.15
	21	36.68	10.66	27.56

Table 2. Colour measurement data (CIE*Lab*) of bread ***crumb*** fortified with different percentages of apple pomace (AP) or brewers' spent grain (BSG) and from control samples (those without AP or BSG)

Level of DF substitution	Baking time [min]	*L**	*a**	*b**
Control	0	83.86	-1.69	16.54
	7	77.37	-1.66	16.75
	14	75.94	-1.27	17.72
	21	75.26	-0.83	19.68
5 % BSG	0	74.04	0.96	15.00
	7	70.82	1.17	15.37
	14	69.57	1.47	15.49
	21	69.42	1.99	15.63
10 % BSG	0	70.09	2.36	14.96
	7	65.24	2.38	15.16
	14	62.77	2.69	15.88
	21	61.99	3.07	15.92
15 % BSG	0	68.11	3.19	15.88
	7	58.76	3.39	16.21
	14	57.36	3.60	16.24
	21	56.54	3.61	16.34
5 % AP	0	67.51	5.34	23.01
	7	61.85	5.38	23.74
	14	55.11	8.00	25.10
	21	49.11	8.36	26.02
10 % AP	0	64.65	6.13	20.19
	7	57.47	6.97	24.39
	14	47.39	10.35	24.59
	21	41.26	10.66	25.23
15 % AP	0	60.64	7.84	16.00
	7	51.80	8.42	20.30
	14	40.72	9.42	25.12
	21	35.77	10.23	27.56

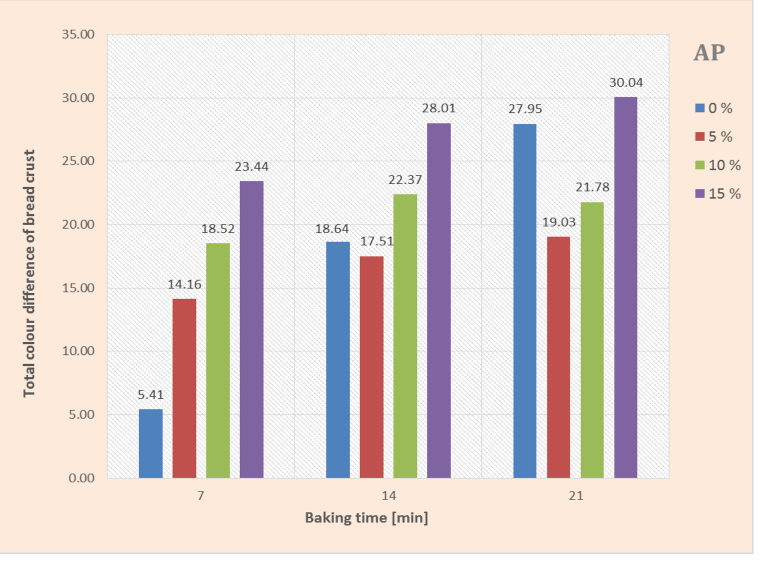

Figure 1. Total colour difference (Δ*E*) of bread ***crust*** fortified with different percentages of apple pomace (AP) and control samples (those without AP)

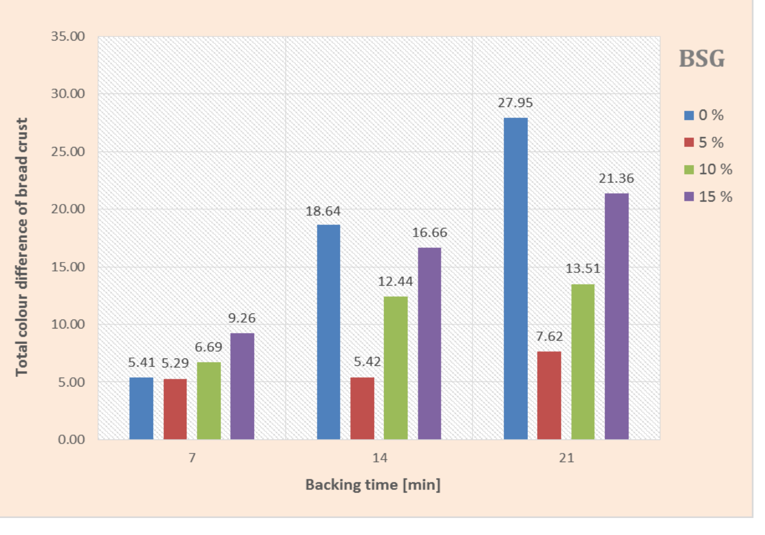

Figure 2. Total colour difference (Δ*E*) of bread ***crust*** fortified with different percentages of brewers' spent grain (BSG) and control samples (those without BSG)

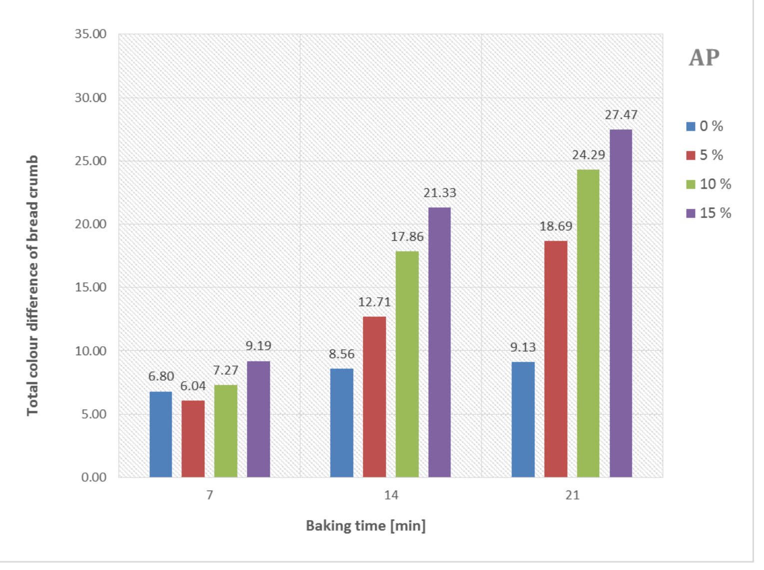

Figure 3. Total colour difference (ΔE) of bread ***crumb*** fortified with different percentages of apple pomace (AP) and control samples (those without AP)

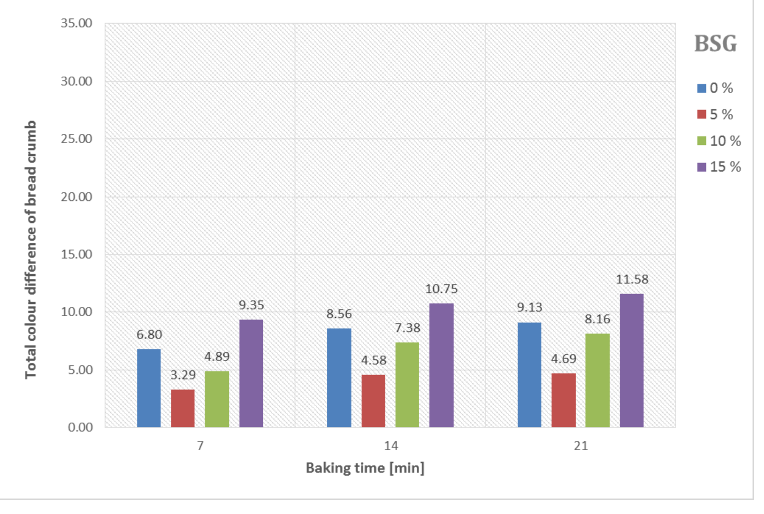

Figure 4. Total colour difference (ΔE) of bread ***crumb*** fortified with different percentages of brewers' spent grain (BSG) and control samples (those without BSG)

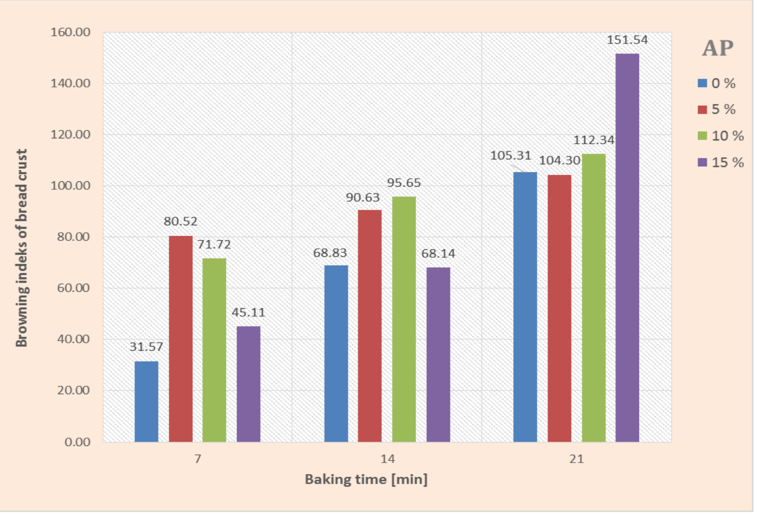

Figure 5. Browning index (BI) of bread ***crust*** fortified with different percentages of apple pomace (AP) and control samples (those without AP)

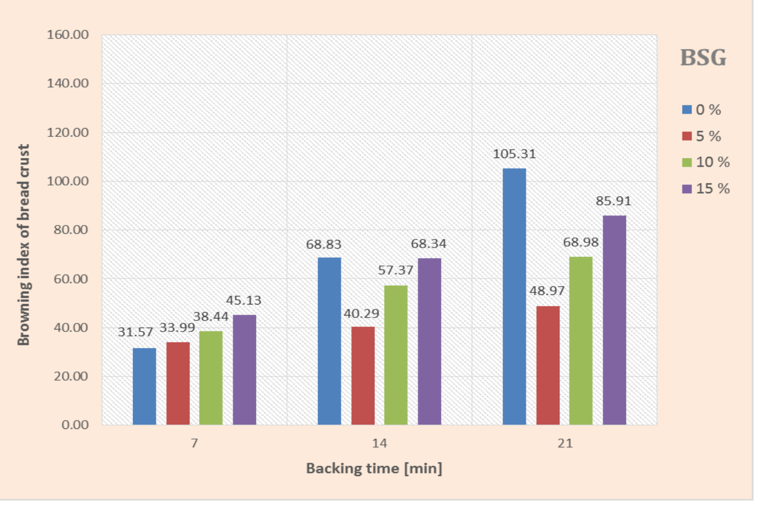

Figure 6. Browning index (BI) of bread ***crust*** fortified with different percentages of brewers' spent grain (BSG) and control samples (those without BSG)

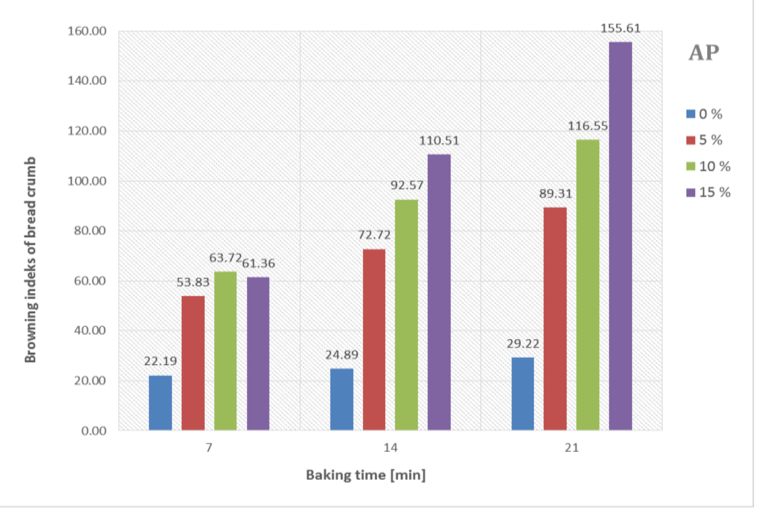

Figure 7. Browning index (BI) of bread ***crumb*** fortified with different percentages of apple pomace (AP) and control samples (those without AP)

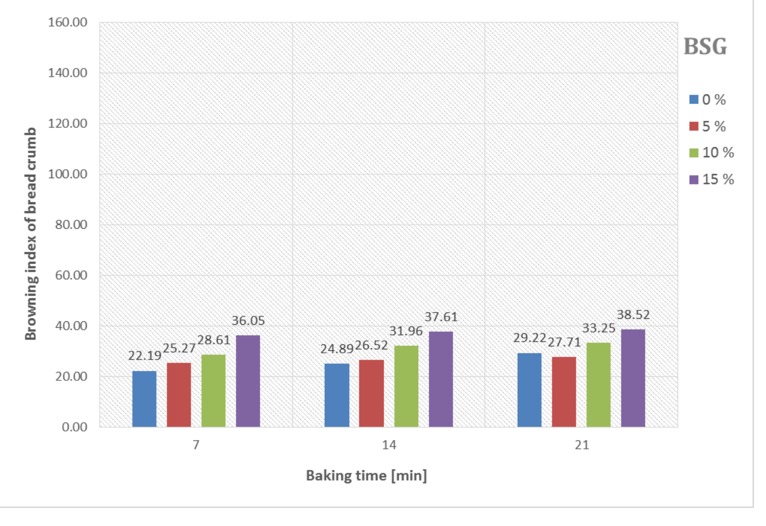

Figure 8. Browning index (BI) of bread ***crumb*** fortified with different percentages of brewers' spent grain (BSG) and control samples (those without BSG)

CONCLUSIONS

An important difference in bread crust colour was observed only when AP and BSG were used. This difference was related to the low lightness L^* in comparison with the control samples as consequence of its darker colour. However, bread samples fortified with BSG baked 14 and 21 min were lighter (lower ΔE, and BI values) than the control. Bread samples fortified with AP were significantly darker (possessed a lower L^* value; higher ΔE, and BI values) than non-fortified ones (control), and this trend became more marked with increasing percentages of DF. The colour difference. ΔE (taking the control bread colour as reference) shows the influence of fiber additions on the bread colour. Although the original colour of ingredients can have some influence on the crust bread colour this is mainly associated to Maillard and caramelization reactions. The crumb bread colour is usually similar to the colour of the ingredients because the crumb does not reach as high temperatures as the crust. In conclusion, fibres from AP and BSG could be recommended as improver in the bread making industry. AP also has the potential for use in bread making as a good source of polyphenols, which has antioxidant properties.

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