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Effect of Broccoli Powder Incorporation on Physicochemical Properties of Cookies

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Abstract

Freeze-dried broccoli powder was incorporated into cookie dough at 5 levels (0, 1, 2, 3, and 4%, w/w) by replacing equivalent amount of wheat flour of the cookie dough. After aging and sheeting, cookies were baked at 170°C for 8 min in an oven. The baked cookies were cooled to room temperature for 1 hr and packed in airtight bags prior to all measurements. The pH and moisture content were ranged 6.74-6.90 and 2.67-4.12% (wet basis) depending on the broccoli powder level, respectively. Lightness (L*-value), redness (a*-value), and hardness decreased while yellowness (b*-value) increased significantly as the broccoli powder content increased (p<0.05). Spread factor of the control was significantly lower than that of samples containing broccoli powder regardless of the concentration (p<0.05) and increased significantly with increase in broccoli powder content (p<0.05). The broccoli concentration correlated significantly with most of properties except for pH and spread factor (p<0.05 or p<0.01). Hardness correlated negatively with moisture content (p<0.05) but correlated positively with spread factor (p<0.01).

Key words: cookies, broccoli, powder, incorporation, physicochemical properties

Introduction

Modern food processing is aimed at manufacturing safe, convenient, and health-promoting food products. Consumers are getting more interests in healthy foods and their functional properties. Cookies have been one of the most favored baking products by many types of consumers as a snack, refreshments, or dessert.

Recently many studies were reported for the quality of cookies added or substituted with various functional food ingredients; for example, potato peel (Han et al., 2004), black rice flour (Lee et al., 2005; Lee et al., 2006; Lee & Oh, 2006; Park & Chang, 2008), dried sweet pumpkin powder (Lee et al., 2005), dried red ginseng powder (Lee et al., 2006), sea tangle powder (Cho et al., 2006), cactus powder (Han et al., 2007), dietary fiber (Uysal et al., 2007), garlic juice (Shin et al., 2007), gluten-soy protein blends (Singh & Mohamed, 2007), onion powder (Kim et al., 2007), soybean paste powder (Jung et al., 2008), yam powder (Joo et al., 2008), and strawberry powder (Lee & Ko, 2009).

There has been a compelling evidence over the past 20 years to link increased consumption of fruits and vegetables, especially cruciferous vegetables, with reduced incidence of many types of cancer (Michaud et al., 1999; Talalay, 1999). Intake of the cruciferous vegetable such as broccoli as little as 10 g/day in a diet significantly reduced the risk of a number of cancers (Kohlmeier & Su, 1997; Price et al., 1998). Broccoli also contains substantial amount of antioxidants, vitamin C, and phenolic compounds (Zielinski et al., 2002) which are known to prevent the onset of chronic disease (Kaur et al., 2007). Furthermore, broccoli is rich in sulforaphane which has been shown to have anticarcinogenic properties (Sivakumar et al., 2007).

Despite previous investigations, to the best of our knowledge, no study has been reported so far on the quality of cookies incorporated with broccoli powder. Attempts were made to produce a snack while taking advantages of functional properties of broccoli. The objectives of present study was to provide reliable experimental data for cookies made with broccoli powder and investigate the effects on cookie making properties.

Materials and Methods

Preparation of raw materials

Fresh broccoli, harvested in April 2008, were obtained from Chungtaesan Farm of Hoengseong-gun, Gangwon-do, Korea. The soft wheat flour (1st grade; CJ Corp., Seoul, Korea),

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granulated sugar (CJ Corp., Incheon, Korea), butter (Seoul Milk Coop., Yongin, Gyeonggi-do, Korea), baking powder (Yuchung Foods Co., Ltd., Daegu, Korea), roasted salt (Bora Food Co., Ltd., Naju, Jeonnam, Korea), powdered skim milk (Seoul Dairy Co-op, Yangju, Gyeonggi-do, Korea), and eggs were procured from a local market and stored at room temperature before use. One hundred grams of the soft wheat flour contained 77 g of carbohydrates, 5 g of protein, 1.5 g of lipids, and 10 mg of sodium.

Prewashed broccoli was steam blanched for 5 min at 100°C after removal of stem. Surface moisture of the sample was removed by cooling at room temperature for 1 hr, then lyophilized using a freeze dryer (FDU-1100, Tokyo Rikakikai Co., Tokyo, Japan) at a vacuum pressure of 8.5 Pa after being frozen at -80°C for 24 hr in a deep freezer (VLT 1450-3-D-14, Thermo Electron Corp., Asheville, NC, USA). Dehydrated broccoli was milled using an analytical mill (DA-282, Daesung Artlon Co., Ltd., Paju, Gyeonggi-do, Korea) at maximum speed for 90 s and sieved to yield particle sizes less than 150 μm. Broccoli powders were then placed in a desiccator containing silica gel prior to cookie making which took within a day.

Cookie preparation and baking

Ingredients were mixed in a Kitchen Aid mixer (model 5K5SS, Whirlpool Corp., St. Joseph, MI, USA) using a flat beater attachment as described in AACC method 10-52 (AACC, 2000a) by substituting 0-4% (based on the total weight of the soft wheat flour and broccoli powder mixture) of broccoli powder according to the formulation given in Table 1. The dough was aged for 2 hr in a 4°C refrigerator and then sheeted to a thickness of 0.4 cm with the help of a rolling pin. The cookies were cut with a cookie cutter of diameter 4 cm and transferred to a lightly greased baking tray. The cookies were baked at 170°C for 4 min, then rotated the tray and baked for another 4 min in a multi-functional convection oven (model GOR-704C, TongYang Magic Corp., Seoul, Korea). The baked cookies were cooled to room temperature for 1 hr and packed in airtight bags.

Table 1. Cookie dough composition, substituted with different percentages of broccoli powder

Ingredients (g)	Broccoli powder level in cookies (%)				
	0	1	2	3	4
Soft wheat flour	300	297	294	291	288
Broccoli powder	0	3	6	9	12
Granulated sugar	150	150	150	150	150
Butter	135	135	135	135	135
Baking powder	1.5	1.5	1.5	1.5	1.5
Salt	1.5	1.5	1.5	1.5	1.5
Egg	75	75	75	75	75
Powdered skim milk	9	9	9	9	9
Total	672	672	672	672	672

pH and moisture analyses

A total of 5 g of cookie sample was blended with distilled water (cookie : water = 1 : 9, w/w) for 1 min. The pH of the sample was determined using a PHM210 Standard pH meter (Radiometer Analytical, Lyon, France). Moisture content of the baked cookies was determined using a convection oven at 105°C overnight. All measurements were done in triplicate.

Color and texture analyses

CIE color characteristics (L^*, a^*, and b^*) of baked cookies were determined using a chromameter (model CR-200, Minolta Co., Osaka, Japan) calibrated with a calibration plate using $Y = 94.2$, $x = 0.3131$, and $y = 0.3201$. The Chromameter used xenon pulse-diffused illumination (D65 illuminant) with three response detectors set at 0° viewing angle. In addition, the machine was preset to use the 2° observer. Color was measured at the same location (one in center and 4 measurements at the edges for each top and bottom sides) using three baked cookies for each treatment and mean values were reported.

Hardness of twenty cookies was evaluated measuring the peak breaking force (N) using the three-point break (triple beam snap) technique with a computer-controlled Advanced Universal Testing System (model LRX*Plus*, Lloyd Instrument Ltd., Fareham, Hampshire, UK) at room temperature. The crosshead speed was 1 mm/s and span between the two platforms was 40 mm.

Spread factor measurement

The spread factor was measured according to AACC 10-50D (AACC, 2000b) and it was calculated as follows:

$$\text{Spread factor} = W/T \times 10$$

where W is the average width of six cookies in mm, and T is the average thickness of six cookies in mm.

Statistical analysis

The statistical analysis was done using the SAS Statistical Analysis System for Windows v9.1 (SAS Inst. Inc., Cary, NC U.S.A.). The means were compared with Duncan's Multiple Range test at the 5% level of significance and Pearson

Table 2. Effect of broccoli powder incorporation on pH and moisture content of cookies

Property	Broccoli powder level in cookies (%)				
	0	1	2	3	4
pH	6.80±0.04^{ab}	6.90±0.09^{a}	6.80±0.06^{ab}	6.74±0.04^{b}	6.77±0.04^{b}
Moisture content (%, wb)	2.67±0.05^{b}	2.97±0.41^{b}	3.12±0.47^{b}	3.90±0.14^{a}	4.12±0.09^{a}

$^{a-b}$Means±SD within the same row without a common letter are significantly different (p<0.05).

correlation coefficients were also determined.

Results and Discussion

pH and moisture content

pH, moisture content, and specific volume as influenced by broccoli powder content are summarized in Table 2. The pH values were ranged from 6.74 to 6.90 depending on the broccoli powder level in the cookies. The values appeared to decrease as the broccoli incorporation level increased in the formulation but differences were not be noticeable regardless of statistical significance. Others reported different ranges of pH values apparently due to different food ingredients incorporated in their formulations: 5.56-6.09 for black rice (0-20%) cookies (Lee et al., 2005), 6.47-7.03 for onion (1.15-8.86%) cookies (Kim et al., 2007), and 5.42-6.68 for strawberry (0-6%) cookies (Lee & Ko, 2009), respectively.

Moisture content of cookies varied from 2.67 to 4.12% (wb) depending on the broccoli content. It was observed that major portion of moisture inside of dough disappeared during baking and there was a clear relationship between moisture content and broccoli content. Similar increase in the moisture content with the higher levels of black rice flour (Lee & Oh, 2006), brown rice flour (Lee & Oh, 2006), or sea tangle powder (Cho et al., 2006) incorporation was reported. Again various ranges of moisture content were reported depending on the food ingredients incorporated: 1.66-2.40% for black rice (0-20%) cookies (Lee et al., 2005), 3.31-5.95% for sea tangle (0-9%) cookies (Cho et al., 2006), 1.23-2.01% for black rice (0-30%) cookies (Lee & Oh, 2006), and 1.22-2.09% for brown rice (0-30%) cookies (Lee & Oh, 2006), respectively.

Color

Changes of color parameters (L*-, a*-, and b*-value) as influenced by broccoli powder content are given in Table 3. Lightness (L*) decreased significantly as the broccoli powder content increased (p<0.05). The L*-value of the control was 75.47, which was significantly higher than others (p<0.05) and the value is comparable with the one reported by others (Cho et al., 2006; Lee & Ko, 2009). Similar decrease in the L*-values with the incorporation of various types of food ingredient in the cookie batter formulation was reported (Lee et al., 2005; Cho et al., 2006; Shin et al., 2007; Lee et al., 2008).

Table 3. Effect of broccoli powder incorporation on color characteristics of cookies

Broccoli powder (%)	Color parameter			
	L*	a*	b*	ΔE
Control	75.47±0.91^{a}	-1.56±0.45^{a}	36.69±0.46^{c}	-
1	71.92±1.09^{b}	-4.43±0.80^{b}	37.29±0.85^{b}	4.77±0.70^{d}
2	69.92±0.79^{c}	-6.39±1.33^{c}	37.58±0.59^{b}	7.57±0.49^{c}
3	68.74±0.93^{d}	-8.83±0.84^{e}	38.06±0.54^{a}	10.09±0.29^{b}
4	66.08±0.52^{e}	-7.81±0.39^{d}	38.31±0.32^{a}	11.40±0.46^{a}

$^{a-e}$Means±SD within the same row bearing unlike letters are significantly different (p<0.05).

Redness (a*-value) decreased while yellowness (b*-value) increased significantly as the broccoli powder content increased in the formulation (p<0.05) and they ranged from -1.56 to -7.81 and 36.69 to 38.31, respectively. The total color difference (ΔE) values also increased significantly with increase in broccoli powder content (p<0.05). These changes in overall color characteristics are inherent with distinctive color characteristics of food ingredients used in the formulation and it is partially due to the degradation of color

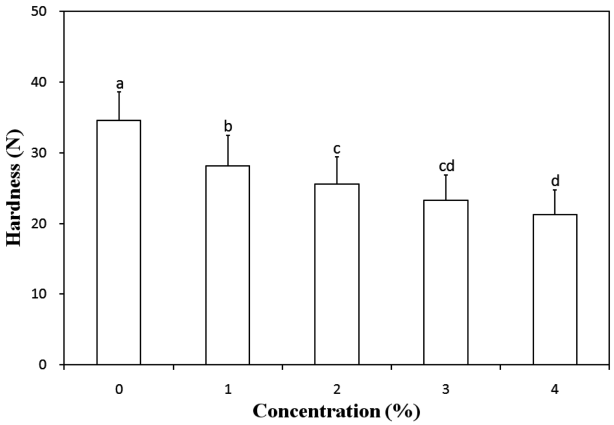

Fig. 1. Effect of broccoli powder incorporation on hardness of cookies. Means without a common letter are significantly different (p<0.05).

pigments such as chlorophyll and β-carotene during baking at such high temperature.

Texture

Changes of cookie hardness as influenced by broccoli powder incorporation is shown in Fig. 1. Hardness decreased significantly with increase in broccoli powder content ($p<0.05$). Similar decreases in the hardness were reported for cookies incorporated with other types of food ingredients such as potato peel (Han et al., 2004), black rice flour (Lee & Oh, 2006), brown rice flour (Lee & Oh, 2006), resistant starch (Kang & Lee, 2007), garlic juice (Shin et al., 2007), and strawberry powder (Lee & Ko, 2009). However, it should also noted that there was no significant effect of incorporation of shredded garlic (Kim et al., 2002) or functional rice flour (Kim et al., 2002) on cookie texture.

Spread factor

Spread factor of the control was significantly lower than that of samples containing broccoli powder regardless of the concentration ($p<0.05$) and increased significantly with increase in broccoli powder content ($p<0.05$) (Fig. 2). Singh & Mohamed (2007) reported that the spread factor decreased as the protein content of cookies increased. Incorporation of broccoli powder in the formulation replaced the soft wheat flour and in turn total amount of protein reduced; as a result, spread factor increased. Similar increases in the spread factor were reported for cookies incorporated with potato peel (Han et al., 2004), *Rhynchosia volubilis* (Ko & Joo, 2005), black rice flour (Kim et al., 2006), and strawberry powder (Lee & Ko, 2009).

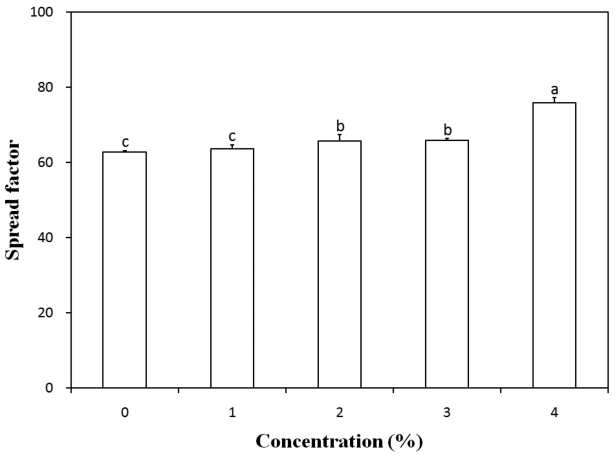

Fig. 2. Effect of broccoli powder incorporation on spread factor of cookies. Means without a common letter are significantly different ($p<0.05$).

Correlation between properties

Table 4 presents the correlation between physicochemical properties for cookies incorporated with different levels of broccoli powder. The broccoli concentration correlated significantly with most of properties except for pH and spread factor ($p<0.05$ or $p<0.01$). Properties such as moisture content, *b**-value, and *ΔE* correlated positively while *L**-value, *a**-value, and hardness correlated negatively. None of the properties correlated significantly with pH. Hardness correlated negatively with moisture content ($p<0.05$) but correlated positively with spread factor ($p<0.01$).

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Table 4. Correlation between physicochemical properties for cookies incorporated with different levels of broccoli powder

	Broccoli concentration	pH	Moisture content	Color parameters				Hardness
				*L**	*a**	*b**	*ΔE*	
pH	-0.578^{NS}							
Moisture content	0.971**	-0.628^{NS}						
*L**	-0.985**	-0.449^{NS}	-0.928*					
*a**	-0.924*	-0.545^{NS}	-0.899*	0.922*				
*b**	0.990**	-0.518^{NS}	0.965**	-0.987**	-0.958*			
ΔE	0.979**	-0.514^{NS}	0.934*	-0.985**	-0.974**	0.993***		
Hardness	-0.965**	0.413^{NS}	-0.910*	0.988**	0.960**	-0.986**	-0.993***	
Spread factor	-0.860^{NS}	-0.181^{NS}	-0.799^{NS}	0.918*	0.916*	-0.914*	-0.929*	0.961**

^{NS} Not significant, * Significant at $p<0.05$, ** Significant at $p<0.01$, *** Significant at $p<0.001$.

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