Physicochemical and textural properties of pork patties as affected by buckwheat and fermented buckwheat

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Abstract This study was investigated to assess the effects of buckwheat (BW) and fermented buckwheat (FBW) on the proximate compositions, pH change, cooking quality, lipid oxidation, textural properties, and sensory characteristics of pork patties. Pork patties treated with BW and FBW were divided into six groups; Con, non-treated patties; T0, reduced fat patties; T1 and T2, addition of 1 and 3 % BW; FT1 and FT2, addition of 1 and 3 % FBW. FBW showed significantly higher antioxidant activity and total phenolic contents than BW ($P < 0.05$). FT2 had significantly lower level of lipid oxidation than other groups ($P < 0.05$). The addition of BW and FBW increased the crude fiber content in pork patties, whereas it decreased the crude fat content compared to the control group ($P < 0.05$). BW and FBW significantly reduced expressible drip and cooking loss ($P < 0.05$). Pork patties prepared with BW and FBW exhibited

higher redness value of uncooked and cooked patties. Texture profile analysis of patties revealed that the addition of BW and FBW significantly decreased the hardness and increased tenderness. The results suggested that BW and FBW exhibited substantial effects on improving the quality of pork patties. The 1 % BW (T1) and FBW (FT1) appeared to be the most effective means of improving the overall properties of pork patties.

Keywords Buckwheat · Fermented buckwheat · Antioxidant activity · Pork patties

Introduction

Meat products contain relatively high animal fat content with a range of 30–50 %, depending on the processed products (Jiménez-Colmenero 2000; Woo et al. 1995). Fat generally provides important technological functions for water holding capacity and sensory properties such as flavor and texture in meat product manufacture (Mendoza et al. 2001; Wirth 1988). However, animal fat has high amounts of saturated fatty acids and cholesterol, and high animal fat intake could cause adverse cardiovascular effects on coronary heart disease, stroke and hypertension (Kannel 1996; Law 1997; Ozvural and Vural 2008). Because of health disadvantages with excessive fat intake, there have been increasing interests on healthier diets among consumers and development of reduced fat meat products by the substitution of animal fat with vegetable oils and other ingredients such as dietary fiber and isolated soy protein (Ansorena and Astiasarán 2004; Choi, Choi et al. 2009; Del Nobile et al. 2009; Mora-Gallego et al. 2013; Park et al. 2005).

Research highlights

- Buckwheat (BW) and fermented buckwheat (FBW) increased the crude fiber and decreased crude fat contents in pork patties.
- FBW had considerably higher antioxidant activity and the total phenolic contents.
- Patties processed with FBW had significantly lower lipid oxidation during storage.
- Pork patties prepared with BW and FBW exhibited higher redness value of uncooked and cooked patties, and had lower expressible drip and cooking loss.
- BW and FBW significantly decreased the hardness and increased tenderness.

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Buckwheat (*Fagopyrum esculentum* Moench) has been used as a basic functional ingredient in food industry, such as noodles, pasta, bread and other type of food products. Buckwheat is classified as a pseudo cereal from the general cereal family (Aufhammer 2000). Buckwheat has plentiful amounts of dietary fiber, rutin, and essential minerals. Moreover, buckwheat contains a relatively high amount of lysine (64 mg/g) and includes a large amount of several vitamins, such as B1, C, and E (0.46, 5.00, and 5.46 mg/100 g), respectively (Wijngaard and Arendt 2006). In addition, buckwheat contains excellent nutritional quality, showing the high essential amino acids values, digestibility and bioavailability of amino acids (FAO 1990). Especially, flavonoids such as rutin and quercetin in buckwheat exhibit a higher level of antioxidant activity than ascorbic acid, α -tocopherol and β -carotene (Rice-Evans et al. 1997). In general, the aglycones have much higher potent antioxidant activity than their corresponding glycosides (Yin et al. 2008). Rice-Evans et al. (1997) found that quercetin (aglycone) showed the higher antioxidant activity compared to rutin (glycoside). According to Niveditha and Sridhar (2012), phenolic compounds and free radical scavenging activity of fermented products were increased by the fermentation with various microorganisms. *Rhizopus oligosporus* is particularly considered as a traditional microorganism for producing fermented foods as it is Generally Regarded As Safe (GRAS). Moreover, the increment of antioxidant activity was reported after the fermentation with *Rhizopus oligosporus* (Niveditha and Sridhar 2012).

In the meat processing industry, consumers' acceptance and awareness for functional meat products have been gradually increased, and several organic products have been considered as substitute additives instead of synthetic chemical additives (Choi et al. 2012; Hathwar et al. 2012; Haugaard et al. 2014). Grains are mainly utilized for improving meat products quality characteristics due to the plentiful starch and fiber contents (Yi et al. 2012; Petersson et al. 2014). Some plant species including tomato and wheat sprout powder had powerful antioxidants such as phenols, flavonoids, and reducing glycosides, which were demonstrated effectively for inhibition of lipid oxidation in meat products (Kim et al. 2013; Ozturk et al. 2014). Moreover, buckwheat had effects on reducing serum glucose concentrations in diabetic rats and inhibiting lipid oxidation in mouse brain during digestion (Hur et al. 2011; Kawa et al. 2003). Although buckwheat is a good source of nutrients to provide health benefits, there is limited information in the literature on the influence of buckwheat on the

antioxidant activities and nutritional properties of meat products. Therefore, the purpose of this study was to investigate the effects of the buckwheat and fermented buckwheat on the proximate compositions, pH, cooking quality, retardation of lipid oxidation, and textural properties, sensory characteristics of pork patties.

Material and methods

Preparation of *Rhizopus oligosporus*

The *R. oligosporus* was obtained from Korean Culture Center of Microorganisms (KCCM). One colony was incubated into 10 mL of sterilized potato dextrose broth (PDB, Difco, Detroit, MI) for 24 h at 30 °C before the *R. oligosporus* was inoculated into the buckwheat grains. The activated culture was inoculated into PDB and incubated at 30 °C for 24 h when the viable population was 10 CFU/mL.

Preparation of fermented buckwheat (FB)

The commercial whole buckwheat samples were obtained from Bongpyung Memil Co., Pyengchang, Korea. The proximate chemical compositions of crude protein, ash, fat, starch and total dietary fiber for the common non-fermented buckwheat grain were 21.6, 4.08, 7.20, 40.7, and 26.37 %, respectively (Bonafaccia et al. 2003). The fermented buckwheat was prepared by using a modified method for setting adequate condition up, as described by Handoyo et al. (2006), and used for this study. Buckwheat grains (50 g) were soaked with 100 mL of distilled water for 45 min. The samples were then sterilized by using an autoclave at 121 °C for 15 min. After the sterilization of buckwheat grains, the samples were placed for cooling process at room temperature. The sterilized samples were inoculated with 1 % *R. oligosporus* and put into the incubator (30 °C and 85 % relative humidity) for 24 h. After the fermentation, the fermented samples were freeze-dried for grinding process. The non-fermented and fermented buckwheat samples were properly ground using a blender and passed through a 20 mesh screen. The ground buckwheat samples were then stored in a dark place at refrigerated temperature until ready for use.

Preparation of pork patties

Fresh pork meat (*longissimus dorsi*) and pork back fat were purchased from a local market at 24 h postmortem. Before the manufacture of pork patties, the meat was trimmed for removing visible connective tissue and fats. The pork patties samples were made according to a traditional recipe described by

Table 1 Pork patties formulation (%) with the different levels of buckwheat and fermented buckwheat

	CON	T0	T1	FT1	T2	FT2
Lean meat	70	70	70	70	70	70
Back fat	20	10	10	10	10	10
Ice water	10	20	19	19	17	17
Buckwheat	0	0	1		3	
Fermented buckwheat				1		3
Total	100	100	100	100	100	100
Salt (NaCl)	1.5	1.5	1.5	1.5	1.5	1.5
Garlic powder	3.0	3.0	3.0	3.0	3.0	3.0
Isolated soy protein (ISP)	1.5	1.5	1.5	1.5	1.5	1.5
Sugar	0.8	0.8	0.8	0.8	0.8	0.8

Con, control group; T0, reduced fat patties; T1, addition of 1 % buckwheat (BW); FT1, addition of 1 % fermented buckwheat (FBW); T2, addition of 3 % BW; FT2, addition of 3 % FBW

Jeong et al. 2009. The formulation of pork patties is presented in Table 1. Pork meat was ground through a 5 mm plate and then the back fat was weighted before blending. The basic ingredients (1.5 % salt, 3.0 % garlic powder, 1.5 % isolated soy protein, and 0.8 % sugar) were added into the ground mixtures. The mixtures were blended by hand for 5 min and then ground through the plate repeatedly. The final mixtures were formed into patties (about 100 g each) using sterilized 15 × 90 mm petri dishes. After wrapping with a polyethylene film, the plates were placed into refrigerator at 4 °C during 14 days. All groups were divided into five pork patties with addition of non-fermented buckwheat (1 and 3 %) and fermented buckwheat (1 and 3 %), respectively.

Preparation of extraction from buckwheat

The extraction solvents were prepared with distilled water, ethanol, and 50 % ethanol, respectively. A 50 g of BW and FBW was soaked in a solution for 45 min and then drained. The soaked buckwheat samples were sterilized by using an autoclave. A 100 mL of solvents were added into 50 g of the buckwheat and the mixture was shaken well for 1 h at room temperature. The extraction was filtered with Whatman No.1 filter paper. The extractions were used for estimating DPPH, total phenol, and flavonoid contents in samples.

DPPH assay

The ability of scavenge 1,1-diphenyl- 2- picrylhydrazyl (DPPH) radical by buckwheat and fermented buckwheat

was measured by the modified method of Blois (1958). A 0.1 mL of the buckwheat extraction was added into 2.9 mL of 100 µM DPPH/ethanol solution. The reaction mixture was placed in the dark at room temperature for 20 min. The absorbance was measured at 515 nm using a UV-spectrophotometer (Optizen 2120 UV, Mecasys Co., Korea) L-ascorbic acid was used as a positive control for standard curve. The scavenging activity was calculated by the following equation:

Scavenging activity (%)

$$= \left\{ \frac{(\text{Absorbance}_{\text{Blank}} - \text{Absorbance}_{\text{sample}})}{\text{Absorbance}_{\text{Blank}}} \right\} \times 100$$

Total phenolic and flavonoid

Total phenolic contents of BW and FBW were measured by using a slightly modified Folin-Ciocalteu's method described by Singleton et al. (1999) and Meda et al. (2005). Extracts from FBW and BW was diluted with each solutions (distilled water, ethanol, and 50 % ethanol). A 0.5 mL of diluted extraction was mixed with 2.5 mL of Folin-Ciocalteu reagent (0.2 N). The absorbance recorded at 760 nm after 2 h. The amount of total phenolics was calculated as gallic acid equivalent from the calibration curve using ppm of standard gallic acid solution (Kanto Chemical, Japan).

The measurement of total flavonoid contents was conducted by using a slightly modified method as adapted by Arvouet-Grand et al. (1994) and Meda et al. (2005). A 1.5 mL of 2 % AlCl₃ was reacted with 1.5 mL of the extract for 10 min at room temperature. The absorbance was recorded at 415 nm by using a UV-spectrophotometer (Optizen 2120 UV, Mecasys Co., Korea). Quercetin was used as a positive control for standard curve.

Proximate compositions analysis

The proximate compositions (moisture, crude protein, crude fat, ash and crude fiber) were analyzed using the Association of Official Analytical Chemists (AOAC 2002) methods.

pH, expressible drip, and cooking loss

The pH values of the uncooked patties were measured with a pH meter (pH 900, Precisa Co, Switzerland). A 2 g of the patty was homogenized with 18 mL distilled water for 90 s, using a Bag mixer 400 (Interscience Co, France). Expressible drip was measured according to the method of Ng (1987). Samples were placed between two Whatman No.1 filter papers, and pressed with 9.9 kg/cm² force for 2 min (IF 32B-S50, Ilshin Tech. Co. Ltd., Korea). The pressed sample was weighed after removal from the paper.

Cooking loss was estimated by using the following procedure. The patties were cooked at 70 °C core temperature for 30 min. The cooked patties were lightly

blotted using standard laboratory paper towels to remove exudate. The cooking loss was calculated by the following equation

$$\text{Cooking loss (\%)} = \{(\text{the weight of raw patty} - \text{the weight of cooked patty}) / \text{the weight of raw patty}\} \times 100$$

Color measurement

The color of patties was measured by using handy colorimeter (NR-300, Nippon Denshoku, Tokyo, Japan). The colorimeter was calibrated with a white plate (CIE $L^* = +94.48$, $a^* = -0.67$, $b^* = +3.31$). Values of CIE L^* (lightness), CIE a^* (redness), and CIE b^* (yellowness) were measured for uncooked and cooked patties, respectively. The patties were stored at room temperature for 20 min before the color measurement.

TBARS determination

Thiobarbituric acid reactive substances (TBARS) of pork patties added with buckwheat and fermented buckwheat were measured during storage (0, 3, 6, and 14 d) by using the method of Witte et al. (1970). A 2 g sample was homogenized with 10 mL of 10 % trichloroacetic acid for 60 s. The homogenized sample was mixed with 10 mL distilled water. The mixture was filtrated through Whatman No. 1 filter paper and then the supernatant was added in 5 mL of 2-thiobarbituric acid. After a heat treatment process for 10 min, the absorbance was measured at 532 nm. TEP (1,1,3,3-Tetraethoxypropane) was used as a positive control for standard curve. The TBARS value was calculated as malondialdehyde (MDA) mg/kg.

Texture analysis and sensory test

Texture profile analysis (TPA) was conducted in triplicate on each sample at room temperature with a TA-XT2i texture analyzer (Stable Micro Systems, Godalming, U.K.). Pork patties was sized designed approximately $5.0 \times 5.0 \times 1.5$ cm. Samples were cut from the central portion of each patties. The conditions of texture analysis were as follows: pre-test speed 2.0 mm/s, post-test speed 5.0 mm/s, maximum load 2 kg, head speed 2.0 mm/s, distance 8.0 mm, force 5 g. The calculation of texture profile analysis values was obtained by graphing a curve using force and time plots. Values for hardness, springiness, cohesiveness, gumminess, and chewiness were determined as described by Bourne (1978).

The sensory evaluations were conducted in duplicate on each sample by panelists. Ten members of the selected and trained panelist were from the Department of Food Science

and Biotechnology of Animal Resources, Konkuk University in Korea, who were trained and experienced in various types of sensory tests. The sensory evaluation was performed in accordance with the procedure as described by Lawless and Heymann (1998). Pork patties were cooked to a core temperature of 75 °C and cooled to room temperature. Before the preparation of sensory evaluation, samples were cut into quarters (size: $5.0 \times 5.0 \times 1.5$ cm). Each sample coded with a randomized 3- digit number was served to the panelists. Each sample was placed on white plate under fluorescent lighting. The color (1 = extremely undesirable, 10 = extremely desirable), flavor (1 = extremely undesirable, 10 = extremely desirable), tenderness (1 = extremely tough, 10 = extremely tender), juiciness (1 = extremely dry, 10 = extremely juicy) and overall acceptability (1 = extremely undesirable, 10 = extremely desirable) of the cooked samples were tested using a 10 point descriptive scale.

Statistical analysis

A 6 treatment $\times$ 4 storage periods factorial design with triplicates was used in a one-way analysis of variance (ANOVA). All data were analyzed at least in triplicate and mean values were reported. Statistical analyses were carried out with the General Linear Model (GLM) procedure of the SPSS version 18.0 using one- way analyses of variance. Differences between group means and storage periods were determined using Tukey test, and were considered to be significant at $P < 0.05$.

Results and discussion

Proximate composition, cooking loss, expressible drip and pH

The moisture content of reduced fat patties (T0) was significantly higher than that of other groups ($P < 0.05$), and the moisture contents of buckwheat (BW) and fermented buckwheat (FBW) groups were decreased as added BW and FBW contents were increased (Table 2). This result was caused by the initial formation of reduced fat pork patties having more water and less fat contents compared to the control group

Table 2 Proximate composition, cooking loss, expressible drip, and pH value of uncooked pork patties added with buckwheat and fermented buckwheat

	Treatments						SEM	P-value
	Con	T0	T1	FT1	T2	FT2		
Moisture (%)	63.80 ^c	71.44 ^a	69.01 ^{ab}	66.66 ^{ab}	68.62 ^{bc}	65.69 ^c	0.86	<0.001
Crude protein (%)	18.90 ^a	16.99 ^b	17.08 ^b	16.51 ^b	16.95 ^b	17.01 ^b	0.22	<0.001
Crude fat (%)	9.31 ^a	5.01 ^b	4.39 ^b	3.04 ^b	6.20 ^b	6.29 ^b	0.82	<0.001
Ash (%)	2.32 ^{ns}	2.28	2.30	2.31	1.99	2.35	0.18	0.45
Crude fiber (%)	1.57 ^a	0.51 ^d	0.67 ^c	0.37 ^d	1.17 ^b	1.50 ^a	0.04	<0.001
Cooking loss (%)	16.02 ^{cd}	22.49 ^a	20.77 ^{ab}	19.04 ^{bc}	22.04 ^{ab}	15.12 ^d	1.02	<0.001
Expressible drip (%)	37.84 ^{ed}	63.83 ^a	49.67 ^b	42.35 ^c	36.10 ^c	24.15 ^c	1.73	<0.001
pH	5.85 ^c	5.93 ^b	5.96 ^b	5.86 ^c	6.05 ^a	5.94 ^b	0.03	0.001

SEM = standard error of the means ($n = 4$)a–e, Means within the row with different letters are significantly different ($P < 0.05$)

ns, Means within the row are not significantly different

Con, control group; T0, reduced fat patties; T1, addition of 1 % buckwheat (BW); FT1, addition of 1 % fermented buckwheat (FBW); T2, addition of 3 % BW; FT2, addition of 3 % FBW

when added with BW and FBW. Patties processed with 3 % BW and FBW had significantly higher fat content ($P < 0.05$) than 1 % BW (T1) and FBW (FT2). The fat content of buckwheat was combined with the existing fat content of T0. Reduced fat patties and samples containing buckwheat and fermented buckwheat had significantly lower fat content than the control group. Although the samples were added with the different levels of buckwheat, ash contents were not shown a significant difference among all groups ($P < 0.05$). Crude fiber content of patty was increased with the increased amounts of buckwheat added.

Reduced fat patty had significantly higher cooking loss and expressible drip than the control group ($P < 0.05$). The similar result was reported by Mallika et al. (2009). The reduced cooking loss and expressible drip were noticed in buckwheat added samples in this study. Also, both cooking loss and

expressible drip for samples treated with 3 % fermented buckwheat were significantly lower than other groups ($P < 0.05$). This indicated that the addition of fermented buckwheat resulted in an increase of water holding capacity. Lee et al. (2011) also reported that absorption and stability of food was increased with the level of buckwheat concentration. The pH value of reduced fat patties was significantly higher than that of the control group ($P < 0.05$). The pH values for pork patties with fermented buckwheat was lower than buckwheat, and the pH value of FT1 was similar to the control.

Color

The effects of uncooked and cooked patties added with buckwheat on color parameter of lightness, redness and yellowness were summarized in Table 3. Lightness of uncooked and

Table 3 Lightness (L^*), redness (a^*) and yellowness (b^*) of uncooked and cooked pork patties added with buckwheat and fermented buckwheat

Parameter	Treatments						SEM	<i>P</i> -value
	Con	T0	T1	FT1	T2	FT2		
Uncooked								
<i>L</i> [*]	68.39 ^b	72.85 ^a	63.55 ^c	65.32 ^{bc}	64.77 ^{bc}	61.56 ^c	1.32	<0.001
<i>a</i> [*]	2.29 ^c	2.75 ^{bc}	3.27 ^{ab}	2.96 ^b	3.26 ^{ab}	3.72 ^a	0.19	<0.001
<i>b</i> [*]	16.72 ^{bc}	19.14 ^a	16.96 ^b	17.34 ^b	16.14 ^{bc}	15.43 ^c	0.44	<0.001
Cooked								
<i>L</i> [*]	75.00 ^b	76.45 ^a	71.54 ^c	71.91 ^c	67.93 ^d	66.20 ^e	0.34	<0.001
<i>a</i> [*]	0.68 ^b	0.36 ^c	0.42 ^c	0.22 ^c	0.65 ^b	0.93 ^a	0.72	<0.001
<i>b</i> [*]	13.02 ^a	12.33 ^b	10.94 ^c	10.40 ^d	9.53 ^d	9.37 ^d	0.29	<0.001

SEM = standard error of the means ($n = 4$)a–d, Means within the row with different letters are significantly different ($P < 0.05$)

ns, Means within the row are not significantly different

Con, control group; T0, reduced fat patties; T1, addition of 1 % buckwheat (BW); FT1, addition of 1 % fermented buckwheat (FBW); T2, addition of 3 % BW; FT2, addition of 3 % FBW

cooked T0 was significantly higher than that of the other groups ($P < 0.05$). The lightness and yellowness of patties were decreased as BW and FBW concentration increased. In addition, the redness of patties was increased with increasing BW and FBW amount. Similar finding was also reported that the addition of the higher BW on meat products led a reduction of lightness and an increase in redness (Dolatowski and Karwowska 2006). This could be explained that buckwheat contained relatively high rutin content that had a positive correlation with anthocyanins content (Syta et al. 2014). The decrease in lightness and the increase in redness of patties treated with FBW were also reported by Handoyo et al. (2006). Redness and yellowness of cooked patties were decreased, while the lightness of cooked patties was increased compared to uncooked patties.

DPPH, total phenol and flavonoid content

Differences in the DPPH radical-scavenging activity of non-fermented buckwheat and fermented buckwheat is shown in Fig. 1. The percentage for inhibition of free radical by buckwheat extract in descending order was as follows: ethanol extract > ethanol: water (1:1) > water extract. DPPH of fermented buckwheat extraction from three extraction solutions (water; ethanol; water: ethanol, 1:1) was significantly higher than that of non-fermented buckwheat ($P < 0.05$). Ethanol soluble extraction from BW and FBW showed the highest radical-scavenging activity than other extractions ($P < 0.05$). Particularly, free radical scavenging ability of fermented buckwheat from water extraction was higher than non-fermented buckwheat from water extraction.

The total phenol and flavonoids contents of BW and FBW extracts were presented in Fig. 2. Flavonoid contents of BW and FBW by ethanol extract were approximately 1.9 times

Fig. 1 Effect of different solvent extraction of buckwheat and fermented buckwheat on antioxidant activity (DPPH). Data is presented as mean $\pm$ standard deviation ($n = 3$). DW, distilled water BW extract; FDW, distilled water FBW extract; Ethanol, Ethanol BW extract, FEthanol, Ethanol FBW extract; DW: Ethanol, 50 % ethanol BW extract; FDW: Ethanol, 50 % ethanol FBW extract. *a–f* Means with different letters among the different solvents

Fig. 2 Effect of different solvent extraction of buckwheat and fermented buckwheat on total phenolic and flavonoid contents. Data is presented as mean $\pm$ standard deviation ($n = 3$). DW, distilled water BW extract; FDW, distilled water FBW extract; Ethanol, Ethanol BW extract, FEthanol, Ethanol FBW extract; DW: Ethanol, 50 % ethanol BW extract; FDW: Ethanol, 50 % ethanol FBW extract. *a–f* Means with different letters among the different solvents

higher than by water extract. The highest flavonoid content from ethanol extract was 4.96 mg quercetin equivalent/100 g, while the lowest flavonoid content from water extract was 2.68 g quercetin equivalent/100 g. Antioxidant activity of BW was increased by the fermentation process, however, fermentation did not affect the flavonoid contents in BW.

Determination of total phenolic contents in buckwheat could be varied with the extraction solvents and methanol appears to be the most effective solvent for extracting total phenol compounds in buckwheat (Zielinski and Kozłowska 2000). In this study, total phenol compounds of BW and FBW from ethanol extract were significantly higher than water and 50 % ethanol extracts ($P < 0.05$). Besides, total phenol contents of FBW extracts were significantly increased compared to BW extracts ($P < 0.05$). Randhir et al. (2004) also indicated that phenolic antioxidants of fava bean were increased due to the fermentation by using *Rhizopus oligosporus*. Free radical scavenging activity showed positive correlations between total phenol and flavonoid content ($r = 0.81$, $P = 0.01$ and $r = 0.75$, $P = 0.01$).

Effect of buckwheat addition on changes in TBARS of pork patties during storage

The inhibitory effect of buckwheat and fermented buckwheat on pork patties lipid oxidation measured by TBARS is presented in Table 4. TBA value of all groups significantly increased from 0 d to 14 d ($P < 0.001$). Significant differences of

Table 4 Changes in TBARS of pork patties added with buckwheat and fermented buckwheat during refrigerated storage at 4 °C (TBARS, malondialdehyde mg/kg)

Treatments	Storage periods (days)				SEM	P-value
	0	3	6	14		
Con	0.028 ^{ns C}	0.168 ^{a C}	0.286 ^{a B}	0.388 ^{a A}	0.02	<0.001
T0	0.033 ^C	0.172 ^{a C}	0.294 ^{a B}	0.381 ^{a A}	0.02	<0.001
T1	0.031 ^D	0.113 ^{b C}	0.232 ^{b B}	0.361 ^{ab A}	0.01	<0.001
FT1	0.031 ^D	0.113 ^{b C}	0.198 ^{bc B}	0.316 ^{c A}	0.01	<0.001
T2	0.029 ^D	0.114 ^{b C}	0.222 ^{b B}	0.321 ^{bc A}	0.02	<0.001
FT2	0.026 ^D	0.092 ^{c C}	0.170 ^{c B}	0.283 ^{c A}	0.01	<0.001
SEM	0.071	0.071	0.013	0.001		
P-value	0.682	<0.001	<0.001	<0.001		

SEM = standard error of the means ($n = 4$)a–c, Means within a column with different letters are significantly different ($P < 0.05$)

ns, Means within a column are not significantly different

A–D, Means within the row with different letters are significantly different ($P < 0.05$)

Con, control group; T0, reduced fat patties; T1, addition of 1 % buckwheat (BW); FT1, addition of 1 % fermented buckwheat (FBW); T2, addition of 3 % BW; FT2, addition of 3 % FBW

TBA value among all groups were not found at 0 day ($P > 0.05$). The patty samples added with BW and FBW had significantly lower TBA values than the control and T0 group during storages at 3, 6, and 14 d, respectively ($P < 0.05$). This could be explained by the fact that BW and FBW had a more efficient capacity for inhibition of lipid oxidation. Moreover, FT2 demonstrated the highest ability for preventing the lipid oxidation during storage. This result could be related to the increased the free radical scavenging ability by the fermentation that helped produce the more total phenolic compounds and flavonoids. Kariluoto et al. (2006) suggested that fermentation enhanced the total phenolic content and antioxidant ability in cereals. Also, fermented buckwheat had an

excellent antioxidant ability compared to native buckwheat (Dord-ević et al. 2010).

Effect of buckwheat on the textural properties of pork patties

The effects of buckwheat and fermented buckwheat on the textural properties of pork patties were shown in Table 5. Most textural attributes of reduced fat patties were decreased compared to the control group even if there were no significant differences between the control and T0 groups ($P > 0.05$). The textural characteristics of reduced pork patties, such as hardness, gumminess, and chewiness, were decreased with the increased level of BW and FBW. Except for springiness, the significantly lowest values of the textural attributes among all groups were observed in FT2 ($P < 0.05$). Sanderson (1990) demonstrated that springiness could be associated with the degree of appearance recovery. The springiness of noodles had a positive correlation with increased fermented buckwheat added (Handoyo et al. 2006). In this study, the springiness of reduced fat patties was not affected by BW and FBW treatment compared to the control group ($P > 0.05$). The addition of buckwheat grain and seeds as a fat replacement induced the reduction of less hardness when compared to reduced fat meat products (Dolatowski and Dudek 2005; Dolatowski and Karwowska 2006). The addition of buckwheat and fermented buckwheat had contributed to decrease the hardness of pork patties. These results may indicate that the addition of buckwheat or fermented buckwheat powder could be useful for manufacturing reduced fat patties with softer textural properties.

Sensory evaluation

The effects of BW and FBW treatments on sensory properties of pork patties were exhibited in Table 6. The control group and reduced fat patties treated with 1 % BW (T1) and 1 %

Table 5 Textural properties of pork patties added with the different levels of buckwheat and fermented buckwheat

Parameters	Treatments						SEM	P-value
	Con	T0	T1	FT1	T2	FT2		
Hardness	3.42 ^a	3.27 ^{ab}	3.39 ^a	2.55 ^{cd}	2.92 ^{bc}	2.31 ^d	0.63	<0.001
Springiness	6.89 ^{ns}	6.47	6.52	6.37	6.68	6.11	0.09	0.181
Cohesiveness	0.55 ^a	0.53 ^{ab}	0.52 ^{abc}	0.50 ^{bc}	0.51 ^{abc}	0.48 ^c	0.01	0.001
Gumminess	1.87 ^a	1.74 ^{ab}	1.76 ^a	1.28 ^c	1.49 ^b	1.11 ^c	0.41	<0.001
Chewiness	1.26 ^a	1.10 ^a	1.13 ^a	0.80 ^{bc}	0.99 ^{ab}	0.66 ^c	0.35	<0.001

SEM = standard error of the means ($n = 4$)a–d, Means within the row with different letters are significantly different ($P < 0.05$)

ns, Means within the row are not significantly different

Con, control group; T0, reduced fat patties; T1, addition of 1 % buckwheat (BW); FT1, addition of 1 % fermented buckwheat (FBW); T2, addition of 3 % BW; FT2, addition of 3 % FBW

Table 6 Effects of buckwheat and fermented buckwheat on sensory properties of pork patties

Parameters	Treatments						SEM	P-value
	Con	T0	T1	FT1	T2	FT2		
Color	5.75 ^a	5.86 ^a	4.88 ^{ab}	4.75 ^{ab}	3.13 ^b	3.13 ^b	0.67	< 0.001
Flavor	5.16 ^a	4.34 ^{ab}	4.50 ^{ab}	4.33 ^{ab}	3.83 ^{ab}	3.00 ^b	0.80	0.309
Tenderness	4.20 ^b	4.88 ^{ab}	4.00 ^{ab}	4.88 ^{ab}	4.63 ^{ab}	5.66 ^a	0.83	0.035
Juiciness	4.25 ^{ns}	4.25	4.38	5.00	4.88	4.38	0.68	0.852
Overall acceptability	4.88 ^a	4.75 ^a	4.50 ^a	4.63 ^a	3.38 ^{ab}	2.38 ^b	0.57	0.002

SEM = standard error of the mean ($n = 4$)a–b, Means within the row with different letters are significantly different ($P < 0.05$)

ns, Means within the row are not significantly different

Con, control group; T0, reduced fat patties; T1, addition of 1 % buckwheat (BW); FT1, addition of 1 % fermented buckwheat (FBW); T2, addition of 3 % BW; FT2, addition of 3 % FBW

FBW (FT2) did not show significant differences in all sensory characteristics ($P > 0.05$). However, color, flavor and overall acceptability of treatments with 3 % BW and 3 % FBW had the significant lower scores compared to the control and T0 groups ($P < 0.05$). The color score of 3 % BW (T3) and 3 % FBW (FT3) were might be influenced by significant lowering lightness with addition of BW and FBW. The lower flavor score of FT2 could be attributed by the smell generated during the fermentation. Tenderness score for FT2 was significantly higher than the control group ($P < 0.05$). Instrumental texture characteristics of meat products can be closely related to sensory properties (Park et al. 2012). Low hardness score for FT2, estimated by the texture analyzer, may be associated with high tenderness score found in FT2 in this study. Overall acceptability for T1 and FT1 was not significantly different from the control and T0. This suggested that pork patties made from 1 % buckwheat and 1 % fermented buckwheat were comparable or similar to sensory properties of the control and T0.

Conclusions

The introduction of buckwheat and fermented buckwheat yielded considerable changes in physicochemical, lipid oxidation, and textural properties of pork patties. Crude fiber content in pork patties increased, while crude fat content decreased in the presence of buckwheat and fermented buckwheat. Cooking loss and expressible drip were significantly enhanced by the addition of buckwheat and fermented buckwheat. The pH values for the pork patties added with fermented buckwheat had lower than buckwheat. The lightness and yellowness of uncooked and cooked pork patties were decreased, whereas the redness was increased as BW and FBW powder level increased. Moreover, pork patties containing buckwheat and fermented buckwheat exhibited a less hardness value, and the inclusion of buckwheat and fermented buckwheat increased tenderness. The addition of buckwheat

and fermented buckwheat also significantly decreased the lipid oxidation during storage. In conclusion, addition of 1 % BW and 1 % FBW to the patties formulation could be effectively used for enhancing the quality of pork patties.

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