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Effects of Jet-Milled Defatted Soy Flour on the Physicochemical and Sensorial Properties of Hamburger Patties

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Abstract

We investigated the physicochemical and sensorial properties of hamburger patties made with three different defatted soybean flour (DSF) preparations which differed in particle size. Coarse (Dv_{50}=259.3±0.6 μm), fine (Dv_{50}=91.5±0.5 μm), and superfine (Dv_{50}=3.7±0.2 μm) DSF were prepared by conventional milling and sifting, followed by jet milling at 7 bars. Hamburger patties containing 5% of each DSF were prepared for a property analysis. The hamburger patties made with 5% superfine DSF showed the lowest cooking loss among the treatment groups ($p<0.05$). The patties with superfine DSF also retained the texture profile values of the control patties in terms of hardness, gumminess, springiness, and chewiness, while the addition of coarse and fine DSF increased the hardness and chewiness significantly ($p<0.05$). The sensorial results of quantitative descriptive analysis (QDA) indicate that the patties containing superfine DSF were softer and tenderer than the controls ($p<0.05$). Although the overall acceptability of the patties made with coarse and fine DSF was poor, the overall acceptability of the superfine DSF patty was the same as that of the control patty. These results suggest that superfine DSF is an excellent food material that can supply dietary fiber, while maintaining the physical characteristics and texture of hamburger patty.

Keywords   defatted soybean flour, jet mill, superfine powder, hamburger patty

Introduction

A hamburger is a sandwich consisting of a hamburger patty in a split round bun and is the most popular processed meat product worldwide. Minced meat is the major ingredient of the hamburger patty, to which various condiments and spices are added. Although hamburgers are popular, the hamburger has a negative image in terms of human health because hamburgers contain excessive fat, including saturated fatty acids and cholesterol, which are associated with cardiovascular disease (Jiménez-Colmenero, 2000; Fernández-Ginés *et al.*, 2005).

Changes in consumer demand regarding health have affected the composition of hamburger patties. Cereal brans from rice, wheat, oat and rye contribute toward dietary fiber content in meat products and act as a functional ingredient as stabilizer, fat replacer and binder (Choi *et al.*, 2008; Pinero *et al.*, 2008). Extracts from fruit and vegetable such as carrot, persimmon and pumpkin were incorporated into meat products to produce healthier meat products (Eim *et al.*, 2013; Kim *et al.*, 2008). Much effort has been made to produce low-fat hamburger patties to meet consumer demand, although the reduction in fat and moisture also reduces palat-

ability (Ahmed *et al*., 1990; Mansour and Khalil, 1997). The loss of liquids that results from changing the composition of the hamburger patty reduces the sensory outcome and weight of the product, possibly affecting its sales value (Yi *et al*., 2012). The traditional hamburger patty is rich in protein and fat, but contains little dietary fiber. Aside from the health benefits of dietary fiber, a small amount of dietary fiber in a hamburger patty will satisfy current consumer demand for whole foods or unrefined foods.

Defatted soybean flour (DSF) is a by-product that can be obtained in large quantities during the production of soybean oil. DSF contains high levels of dietary fiber, as well as small quantities of proteins, carbohydrates, and fats (Berk, 1992). DSF is a very inexpensive food ingredient. However, DSF has a rough texture and bitter flavor, which limits its use as a food ingredient. Previously, we reported that superfine DSF powder, which has an average particle size of around 5 µm, can be obtained by conventional milling and sifting followed by jet milling (Muttakin *et al*., 2015). Superfine DSF powder had a less rough texture and less bitter taste than conventionally prepared DSF powder. Furthermore, the physical characteristics of superfine DSF powder, such as its water-holding capacity, water-solubility index, and swelling capacity, were improved. These results indicate that superfine DSF powder can be used as a potential food ingredient for fiber enrichment with minimal changes in the physicochemical and sensorial properties of food. Therefore, this study used jet-milled superfine DSF powder to prepare fiber-enriched hamburger patties and verify the effects of the DSF on the physicochemical and sensorial properties of the patties.

Materials and Methods

Materials

Food-grade DSF was obtained from Ho-Kyoung Tech (Korea). Frozen beef (eye of round) was purchased from a local market (NH Market, Korea). Excess fat and connective tissue were removed from the beef with a sharp knife and the trimmed beef was ground through a 4-mm meat grinder and rapidly wrapped in polyethylene and stored at 4°C before use.

Preparation of coarse, fine, and superfine fractions of DSF

The DSF powder was sieved twice (150- and 63-µm testing sieves; Nonaka Rikaki, Japan) to obtain coarse and fine fractions. Those powders that could not pass through the 150-µm sieve were collected as the coarse DSF. The powders that passed through the 150-µm sieve, but that were retained by the 63-µm sieve were collected as the fine DSF. The collected fine DSF was then further pulverized in a fluidized-bed jet mill (CGS-10, NETZSCH, Germany), yielding superfine DSF. Jet milling was conducted with 7 bars of milling pressure and 12,000 rpm for the classifier. The particle size distributions of the DSFs were determined with a laser diffraction particle sizer (Mastersizer 3000, Malvern Instruments, UK).

Preparation of the hamburger patties

The hamburger patties were prepared as follows, using the traditional method: 1) the control hamburger patty was made from 95% lean ground meat and 5% water; 2) the hamburger patty with coarse DSF was composed of 90% lean ground meat, 5% water, and 5% coarse DSF; 3) the hamburger patty with fine DSF was composed of 90% lean ground meat, 5% water, and 5% fine DSF; and 4) the hamburger patty with superfine DSF was composed of 90% lean ground meat, 5% water, and 5% superfine DSF.

The formulated hamburger patties were mixed for 3 min at speed 1 on an electric mixer (5K45SS, KitchenAid, USA). Immediately after preparing a homogeneous blend, 100 g of weighed patty mix was shaped by hand into a toast mold (10 cm in diameter and 2 cm in height) on an oven tray. Sixteen beef patties were cooked in an oven preheated to 180°C to reach an internal temperature of 71°C. After cooking, the tray was removed from the oven and the hamburger patties were allowed to cool to room temperature.

Cooking loss and reduction in patty volume

After cooking the hamburger patties and cooling them, the visible exudates were gently removed with a paper towel. The cooking loss was calculated as follows:

$$Cooking\ loss\ (\%) = \frac{\begin{array}{c}(weight\ of\ raw\ patty\\ -\ weight\ of\ cooked\ patty)\end{array}}{weight\ of\ raw\ patty} \times 100$$

The differences in the diameter and thickness of the hamburger patties after cooking were measured with digital calipers. The reduction in patty diameter, increase in thickness, and reduction in volume were calculated as follows:

Reduction in diameter (%)

$$= \frac{(\textit{diameter of raw patty} - \textit{diameter of cooked patty})}{\textit{diameter of raw patty}} \times 100$$

Increase in thickness (%)

$$= \frac{(\textit{thickness of cooked patty} - \textit{thickness of raw patty})}{\textit{thickness of raw patty}} \times 100$$

Reduction in volume (%)

$$= \frac{(\textit{volume of raw patty} - \textit{volume of cooked patty})}{\textit{volume of raw patty}} \times 100$$

Color measurement

The color of the patties was determined based on the CIE $L*$ (lightness), $a*$ (redness/greenness), and $b*$ (yellowness/blueness) values using a colorimeter (UltraScan Pro, HunterLab, USA). A standard white plate with $L* = 97.4\,9$, $a* = 0.13$, and $b* = 0.04$ was used for calibration. Each sample was measured three times. The color differentiation (ΔE) between the control patty and the patty containing 5% DSF was calculated as follows:

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

Textural profile analysis

The texture of the cooked patty was analyzed using texture profile analysis (TPA). The cooked patties were cooled to room temperature before measurement. Each patty was cut into $2 \times 2 \times 1.5$-cm cubes. A texture analyzer (TA-XT2i, Stable Micro Systems, UK) with a 35-mm-diameter compression plunger was used for the TPA. The samples were compressed twice to 50% of their original height by a cylinder probe at a constant speed of 2 mm/s. The TPA curve was recorded and the hardness, adhesiveness, springiness, cohesiveness, gumminess, and chewiness were calculated automatically (Bourne, 2002).

Sensory evaluation using quantitative descriptive analysis

The sensory properties of the hamburger patty samples were evaluated using the quantitative descriptive analysis (QDA) method, which was specifically developed for meat products (American Meat Science Association, 1995; Selani *et al.*, 2016), with some modifications. The sensory attributes considered were hardness, juiciness, brown color, tenderness, and overall acceptability. Eight panelists were trained using previously identified standard references (Table 1). Cooked patty samples were cut into $2 \times 2 \times 1.5$-cm cubes and assigned random numbers. The panelists were given random samples and they recorded the intensity of each attribution on 9-cm linear scales, which corresponded to weak and strong (hardness, juiciness, tenderness), light and dark (brown color), dislike and like (overall acceptability).

Statistical analysis of the data

All experiments were conducted in triplicate and the results are expressed as the mean $\pm$ standard deviation. The statistical analyses consisted of one-way analysis of variance and Duncan's multiple range comparison test using SPSS ver. 20.0 software (IBM, USA). p-values < 0.05 were considered of significant.

Results and Discussion

Average particle size of the coarse, fine, and superfine DSF

Table 2 shows the particle size distributions of the DSF samples. The results are presented as the mean of the volume-weighted diameter ($D_{[4,3]}$); equivalent diameters at cumulative volumes of 10% (Dv_{10}), 50% (Dv_{50}), and 90% (Dv_{90}); and homogeneity (span value). The average parti-

Table 1. Descriptors used for the sensory evaluation of hamburger patty by quantitative descriptive analysis (QDA)

Descriptor	Definition	References
Hardness	The amount of force required to bite through the sample during the 1st and 2nd chew with the molar teeth	Week: English muffin, Strong: Bagel
Juiciness	Amount of liquid released by the 1st bite	Week: Eye of round steak (cooked to 85°C), Strong: Strip loin steak (cooked to 60°C)
Tenderness	Force needed to obtain deformation and cutting the product by compression between teeth	Weak: Rump steak (cooked to 70°C), Strong: Tenderloin steak (cooked to 65°C)
Brown color	Characteristic color of burger, ranging from light to dark brown	Light: Chicken burger (cooked to 75°C), Dark: beef burger (cooked to 90C)
Overall acceptability	Characteristic satisfaction of human feels	Weak: number 1, Strong: number 9

Table 2. Particle size distributions of the defatted soybean flours (DSFs)

Sample	$D_{[4,3]}$	Dv_{10}	Dv_{50}	Dv_{90}	Span
Coarse DSF	259.3 ± 0.6^a	144.0 ± 1.0^a	246.0 ± 1.0^a	400.3 ± 2.5^a	1.04
Fine DSF	91.5 ± 0.5^b	26.1 ± 0.2^b	81.9 ± 0.3^b	171.1 ± 0.6^b	1.76
Superfine DSF	3.7 ± 0.2^c	0.4 ± 0.1^c	3.6 ± 0.1^c	6.7 ± 0.1^c	1.76

All values are expressed as the mean ± standard deviation. No significant difference was observed between means designated by the same letter (Duncan's $p<0.05$).

cle size can be expressed as either $D_{[4,3]}$ or Dv_{50}. Coarse, fine, and superfine DSF had Dv_{50} values of 259.3±0.6, 91.5±0.5, and 3.7±0.2 μm, respectively. The prepared DSF powders had relative homogeneous size distributions, as indicated by the small span values. Although the DSF samples were prepared as described previously (Muttakin *et al*., 2015), there were some differences in the average particle size due to the different batches of DSF material used. Nevertheless, jet milling effectively pulverized the DSF to a superfine scale (<10 μm) in all cases.

Appearance and color of the hamburger patties

Fig. 1 shows the appearance of the hamburger patties made with different DSFs before and after cooking. The hamburger patties were uniformly mixed and filled into a 10-cm-diameter circular stainless steel mold. Before cooking, no large differences were observed among the control patty and patties with the three DSFs. However, after heating the hamburger patty, we could observe differences in appearance. The control patty decreased in size and a relatively large amount of meat juice drained from the patties. For the hamburger patties made with fine and superfine DSF, the decrease in size was small, as was the amount of juice produced.

Table 2 shows the effect of DSF particle size on the color of the cooked patties. The lightness (L^* value) of the control patty was 50.78±0.62, and it decreased to 44.25±1.48 with the addition of 5% coarse DSF. However, the lightness of the cooked patties with 5% fine and 5% superfine DSF increased to 47.45±0.25 and 47.32± 0.74, respectively, which were similar to that of the control patty. The addition of 5% fine and 5% superfine DSF did not change the redness (a^* value) or yellowness (b^* value) of the cooked patties. The only change was in the a^* value of the patty containing 5% coarse DSF. These results indicate that the addition of 5% fine and superfine DSF minimally affects the color of the cooked patty, which can be confirmed by the small DE values. Similarly, it has been reported that the addition of oat fiber and carrageenan had little effect on the color of cooked hamburger patty (Mittal *et al*., 1992; Hughes *et al*., 1997), while the addition of rice bran fiber changed the cooked color of meat batter (Choi *et al*., 2009).
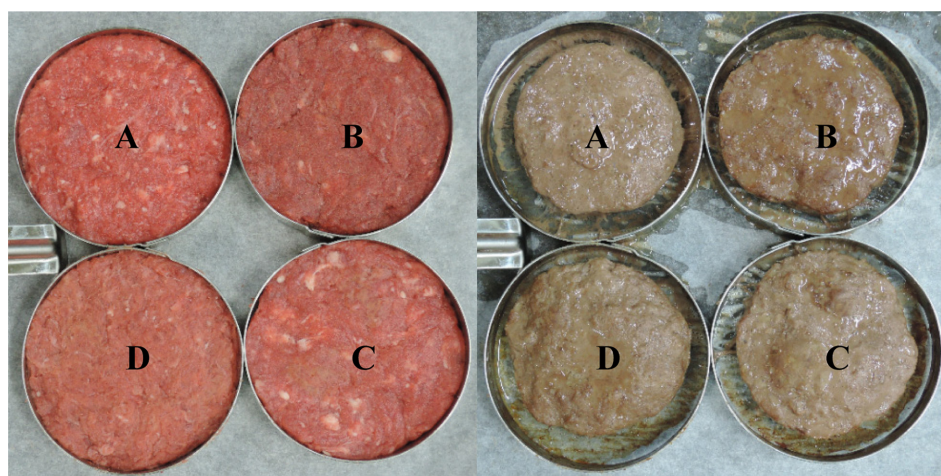

Fig. 1. The appearance of hamburger patty made with 5% DSF powder. (A) Hamburger patty without DSF. (B) Hamburger patty made with 5% coarse DSF. (C) Hamburger patty made with fine DSF. (D) Hamburger patty made with superfine DSF. (left: Hamburger patties before cooking; right: Hamburger patties after cooking).

Cooking loss and volume reduction of hamburger patty

Table 3 presents the cooking loss, reduction in diameter, increase in thickness, and reduction in volume of the hamburger patties made with the different DSFs. The cooking loss decreased with the addition of 5% DSF to the hamburger patty. The cooking loss of the control patty was 34.4%. The addition of coarse and fine DSF to the hamburger patty reduced the losses to 26.4% and 27.2%, respectively. The cooking loss of the patty with superfine DSF was the lowest at 24.8%.

Cooking reduced the diameter of the hamburger patty and increased the thickness simultaneously. The reductions in patty diameter with coarse, fine, and superfine DSF were 18.8%, 18.0%, and 15.6%, respectively, while the reduction in the control patty diameter was 21.2%. The thickness of the patty increased after cooking. Thickness of the control patty increased by 5%, while the thicknesses of the patties with coarse, fine, and superfine DSF increased by 14.3%, 23.2%, and 30.0%, respectively. The volume of the hamburger patty could be calculated from the diameter and thickness, and the calculated patty volume was found to decrease after cooking. The volume loss of the control patty was 34.7%. The addition of coarse and fine DSF to the hamburger patty reduced the losses to 24.6% and 17.3%, respectively. The volume loss of the patty with superfine DSF was the lowest at 7.5%.

The cooking loss reflects the moisture and lipid losses after cooking, which are important determinants of the juiciness and mouth feel of cooked meat (Abdel-Naeem and Mohamed, 2016). The cooking loss is affected by different variables, such as the composition, additives, cooking methods, oven temperature, and sample dimensions (Vittadini et al., 2005). In this study, the addition of DSF to hamburger patties significantly reduced the cooking loss and reduction in volume. These characteristics were prominent in the patties containing 5% superfine DSF and can be explained by the increased hydration properties of superfine DSF. Our previous research indicated that superfine DSF has increased water-holding capacity and swelling capacity of 24% and 32%, respectively, compared with those of coarse DSF (Muttakin et al., 2015).

Textural properties of the cooked patties

Table 5 shows the results of the texture profile analysis

Table 3. Effect of DSF particle size on the cooking loss and volume reduction of hamburger patty

Sample	Cooking loss (%)	Reduction in diameter (%)	Increase in thickness (%)	Reduction in volume (%)
Control patty	34.40 ± 1.67^a	21.16 ± 0.95^a	5.00 ± 4.53^a	34.71 ± 3.76^a
Patty with 5% coarse DSF	28.40 ± 1.67^b	18.76 ± 0.96^b	14.33 ± 5.08^b	24.55 ± 3.30^b
Patty with 5% fine DSF	27.20 ± 1.10^b	18.04 ± 0.87^b	23.17 ± 3.51^c	17.26 ± 2.63^c
Patty with 5% superfine DSF	24.80 ± 1.09^c	15.64 ± 0.85^c	30.00 ± 2.95^d	7.50 ± 1.40^d

All values are expressed as the mean ± standard deviation. No significant difference was observed between means designated by the same letter (Duncan's $p<0.05$).

Table 4. Effect of DSF particle size on the color of cooked hamburger patty

Sample	L^*	a^*	b^*	ΔE
Control patty	50.78 ± 0.62^a	5.45 ± 0.07^a	9.58 ± 0.29^a	-
Patty with 5% coarse DSF	44.25 ± 1.48^c	5.43 ± 0.11^a	7.15 ± 0.76^b	7.04
Patty with 5% fine DSF	47.45 ± 0.25^b	5.54 ± 0.38^a	8.92 ± 0.31^a	3.42
Patty with 5% superfine DSF	47.32 ± 0.74^b	5.51 ± 0.04^a	8.79 ± 0.15^a	3.56

All values are expressed as the mean ± standard deviation. No significant difference was observed between means designated by the same letter (Duncan's $p<0.05$).

Table 5. Texture profile analysis (TPA) of cooked hamburger patty

Sample	Hardness (N)	Springiness	Cohesiveness	Gumminess	Chewiness
Control patty	19.84 ± 2.55^b	0.88 ± 0.02^a	$0.78 \pm 0.01^{a,b}$	15.55 ± 1.94^c	13.67 ± 1.80^b
Patty with 5% coarse DSF	26.34 ± 2.26^a	0.88 ± 0.03^a	0.80 ± 0.01^a	20.97 ± 1.65^a	18.34 ± 1.27^a
Patty with 5% fine DSF	24.26 ± 2.37^a	0.88 ± 0.04^a	0.79 ± 0.02^a	19.17 ± 1.81^b	16.96 ± 1.99^a
Patty with 5% superfine DSF	18.94 ± 2.79^b	0.87 ± 0.03^a	0.77 ± 0.02^b	14.61 ± 1.94^c	12.74 ± 1.54^b

All values are expressed as the mean ± standard deviation. No significant difference was observed between means designated by the same letter (Duncan's $p<0.05$).

of the hamburger patties after cooking. The addition of 5% coarse DSF increased the hardness of the cooked patty significantly from 19.84±2.55 to 26.34±2.26. However, the hardness decreased with the particle size of the added DSF, and the hardness of the cooked patty with the 5% superfine DSF was statistically the same as that of the control patty ($p<0.05$). The hardness of a cooked patty was explained by moisture and fat retention after heating (Choi et al., 2009; Selani et al, 2016). As shown in Table 3, the patty with 5% superfine DSF showed less cooking loss and volume reduction, which indicates that more moisture and fat were retained within the patty after heating, resulting in the reduced hardness value.

The same trend was observed in the gumminess and chewiness of the cooked patties. The addition of coarse DSF increased the gumminess and chewiness significantly, but the gumminess and chewiness decreased with the particle size of the added DSF. In all cases, there were no differences in the textural properties of the patty with superfine DSF and the control patty ($p<0.05$). Springiness and cohesiveness were not affected by the addition of DSF. Previous reports showed that gumminess, springiness, and chewiness decreased when the usage level of vegetable fibers increased, while the addition of 5% rice bran increased only springiness of pork patty (Choi et al., 2008).

Sensory evaluation by QDA

The sensorial properties of the control patty and patties with DSF were analyzed using the QDA method (Table 6). Table 1 shows the five sensorial attributes (hardness, juiciness, tenderness, brown color, and overall acceptability) with the previously identified standards.

The addition of 5% DSF reduced the hardness of the cooked patties. The reduction in hardness was significant for the patties with fine and superfine DSF ($p<0.05$). The hardness measured using the sensory evaluation showed a different tendency from the hardness measured with the TPA due to differences in the measurement methods where

the hardness was judged by the amount of force required to bite through the sample during the 1st and 2nd chews in the sensory test versus the first down-stroke in the TPA test.

The addition of 5% coarse DSF reduced the juiciness of the cooked patty from 4.6±1.5 to 1.6±0.5. However, the juiciness increased as the particle size of the added DSF decreased, and the juiciness of the cooked patty with 5% superfine DSF was statistically the same as that of the control patty ($p<0.05$). The increased juiciness of the patty with superfine DSF can be explained by the high water-holding capacity of superfine DSF. Tenderness did not change with the addition of 5% coarse DSF, while it increased significantly in the patties with fine and superfine DSF ($p<0.05$).

The patties with coarse and fine DSF showed reduced overall acceptability, while the patty with 5% superfine DSF had the same overall acceptability as the control patty ($p<0.05$). The hamburger patty containing superfine DSF was found to be significantly juicier and tenderer than the patties with coarse and fine DSF. The reported overall acceptability of beef patties is mostly affected by juiciness and tenderness (Pinero et al., 2008; Yi et al., 2012) which is in accordance with our result.

Conclusion

Defatted soybean flour is very rich source of dietary fiber. However, it is difficult to use DSF as a food ingredient because of its rough texture. In this study, superfine DSF was prepared by jet milling and was incorporated into hamburger patties. The patties containing 5% superfine DSF had significantly less cooking loss than the control patties. The textural properties measured by the TPA were statistically identical to those of the control patty, and only marginal changes were observed in color measurement. Furthermore, the QDA results indicate that consumers will accept hamburger patties with 5% superfine DSF with the same overall acceptability as control

Table 6. Quantitative descriptive analysis (QDA) of cooked hamburger patty

Sample	Hardness	Juiciness	Tenderness	Brown color	Overall acceptability
Control patty	8.1 ± 0.9[a]	4.6 ± 1.5[a]	3.3 ± 1.9[b]	5.5 ± 1.0[a]	6.1 ± 0.3[a]
Patty with 5% coarse DSF	7.4 ± 1.6[a,b]	1.6 ± 0.5[b]	3.9 ± 1.4[b]	4.6 ± 0.8[a,b]	4.3 ± 0.5[b]
Patty with 5% fine DSF	5.4 ± 2.1[b]	1.8 ± 1.0[b]	5.0 ± 0.5[a,b]	5.4 ± 0.5[a]	3.6 ± 0.8[b]
Patty with 5% superfine DSF	5.5 ± 1.8[b]	4.8 ± 0.6[a]	6.6 ± 1.1[a]	4.0 ± 0.8[b]	6.5 ± 0.7[a]

All values are expressed as the mean ± standard deviation. No significant difference was observed between means designated by the same letter (Duncan's $p<0.05$).

patties. Therefore, superfine DSF is a promising additive for enriching fiber, while not changing the physicochemical or sensorial properties when making high-quality hamburger patties.

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