オカラを添加したソーセージの品質について

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Quality of Sausages Containing 'Okara' Soybean Curd Residue

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Okara is a byproduct of soy milk production. In order to utilize okara and to develop meat products containing dietary fiber, we prepared sausages containing 5, 10, 15, and 20% of okara by substituting cured lean meat with okara (water content, 76%) and compared their quality. Moisture and dietary fiber content, pH, and L* and b* values were increased, while content of protein and lipid and a* value were decreased, in line with an increase in the okara content of the sausage. Addition of 5% okara to sausage sufficiently improved the yield. However, the addition of excessive okara disturbed the gel network structure of the meat protein, and the texture (hardness, springiness, cohesiveness, and chewiness) was significantly impaired in sausages containing ≥15% okara. Sensory evaluation of sausages containing 5% or 10% okara was comparable with that of sausages without okara. Our findings show that the addition of okara can supplement sausages with dietary fiber and improve their water holding capacity and that an okara content of 10% is appropriate for making good quality sausages.

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Key words : *sausage, okara, dietary fiber, texture, sensory evaluation*
ソーセージ，オカラ，食物繊維，テクスチャー，官能評価

Soybean curd residue, okara (also known as soy pulp), is a byproduct of soy milk production and is high in dietary fiber. It is known to have beneficial physiological functions in areas such as suppressing hypertension[1], increasing plasma lipids[2] and obesity[2,3], and exerting prebiotic[3] and antihyperglycemic effects[4]. The volume of okara generated is 10% larger than the volume of the raw material, soybeans[5]. However, because of its high water content and perishable feature, only a small proportion of okara is used for the production of livestock feed[6,7] and cookies[7], while the majority is discarded as waste. This is consequently a burden on the environment[6~8]. Manufacturing of Tofu in Japan, also a soymilk product, is strong and generates a considerable amount of okara, and the common disposal of okara by incineration[9] is costly.

Meanwhile, the adaptation of the western lifestyle in Japan has led to an increase in meat consumption and a decrease in grain and vegetable consumption[10]. Because meat does not contain dietary fiber, the dietary fiber intake in Japan has declined to approximately 15g/day/person[11], which falls far short of the recommended dietary fiber intake specified by the World Health Organization (25g/day/person)[12]. Thus, possib le health problems owing to low dietary fiber intake are of concern.

In this study, we aimed to find a new utilization for okara and to develop a novel processed meat product containing dietary fiber. Thus, we prepared sausages containing various amounts of okara and evaluated their qualities, thereby revealing the appropriate amount of okara as an additive.

Materials and Methods

1. Materials

Okara, recovered immediately after soymilk filtering and stored frozen was obtained from a Tofu manufacture in Toyama, Japan. Frozen okara was thawed before use. Lean pork meat (biceps femoris muscle) and back fat were obtained from CENTRAL FOODS Co., Ltd (Tokyo, Japan).

2. Dry curing

Lean pork meat was chopped into 5cm cubes. Salt, sugar, potassium nitrate, sodium nitrite, sodium ascorbate, and sodium tripolyphosphate were added

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Table 1 Recipe for dry curing (%)

Ingredient	Quantity
Lean pork	100.00
Salt	2.50
Sugar	0.50
Potassium nitrate	0.02
Sodium nitrite	0.01
Sodium ascorbate	0.10
Sodium tripolyphosphate	0.20

according to a recipe (Table 1) and blended with the meat cubes using a meat mixer (MS - 20 ; TAKEUCHI Food Machinery Ltd., Kanagawa, Japan) for 10 min. The mixture was stored for three days at 5℃ to produce cured meat.

3. Preparation of sausage meat

Cured meat and pork back fat were minced with a meat chopper using a grinder plate with holes of 5 mm diameter (OMC-22B, OHMICHI Co., Ltd., Gunma, Japan) and mixed with okara, iced water, and spices according to five formulations (Table 2). The minced - meat mixture was further finely chopped with a silent cutter (OMF-780, OHMICHI Co., Ltd.) and mixed well to produce sausage patties. The weight percent of back fat to the total sum of cured meat, back fat, and okara was uniform (15%) across the five preparations. Lean meat was partially substituted with okara to produce a sausage meat with an okara weight percent of 5, 10, 15, and 20%, and in turn, four sausage meat samples, namely, the 5, 10, 15, and 20% okara sausage samples, respectively. Sausage meat without okara served as a control. Substitution of cured meat with okara resulted in a decrease in salt content in sausage meat. Thus, salt was added to the okara-containing sausage formulations to adjust the salt content to 2.0% in the final sausage meat.

4. Filling of sausage casings and cooking

The sausage meat was uniformly filled into vinyl casings (diameter, 25mm) and incubated in a water bath at 75℃ for 30 min. Cooked sausages were immediately cooled under running water and then refrigerated at 5℃ for 12 h.

5. Composition analysis

The amount of moisture, protein, fat, dietary fiber, and ash was measured as follows : moisture ; the heat drying method under normal pressure[13], protein ; the Kjeldahl method[14], fat ; the chloroform-methanol extraction method (for okara)[15], or the Soxhlet extraction method (for sausages)[16]. d ietary fiber ; the modified Prosky method[17], and ash ; the direct ashing method[18].

6. pH measurement

Okara and sausages were each suspended in distilled water of nine times their weight, and the resultant suspensions were subjected to pH measurement using a pH meter (F-52 ; HORIBA Ltd., Kyoto, Japan).

7. Color measurement

L*a*b* color space values of okara samples and cross-sections of sausages were measured with a spectrophotometer (CM - 3500 d ; Konica Minolta Sensing Inc., Osaka, Japan).

8. Measurement of water holding capacity

The water - holding capacity of okara was measured according to the method recommended by the Japanese Agricultural Standards[19]. Briefly, 6 g of thawed okara was immersed in 20 g of water in a 50㎖ plastic centrifuge tube, allowed to absorb

Table 2 Formulations for sausages with and without added Okara

Ingredient	Rate of okara (%)				
	0 (Control)	5	10	15	20
Cured meat	85.0	80.0	75.0	70.0	65.0
Pork back-fat	15.0	15.0	15.0	15.0	15.0
Okara	-	5.0	10.0	15.0	20.0
Water (ice)	25.0	25.0	25.0	25.0	25.0
Onion	1.5	1.5	1.5	1.5	1.5
MSG[1]	0.1	0.1	0.1	0.1	0.1
White pepper	0.2	0.2	0.2	0.2	0.2
Black pepper	0.1	0.1	0.1	0.1	0.1
Mace	0.1	0.1	0.1	0.1	0.1
Salt	0.50	0.65	0.75	0.90	1.00

[1]: Monosodium glutamate

water for 20 min at room temperature, and then centrifuged at 1,000×g for 5 min. After removal of the supernatant, the pellet was weighted. The water holding capacity was obtained by dividing the weight of the pellet by the dry weight of the okara sample.

9. Observation of sausage cross sections

Cross sections of sausages were observed under a microscope (Tabletop Microscope TM-1000; Hitachi High-Technologies CO., Tokyo, Japan) and by examining images taken by a digital camera (Digital Camera GR DIGITAL III; Ricoh Co., Ltd., Tokyo, Japan).

10. Yield measurement

Refrigerated sausages in their casings were returned to room temperature and centrifuged at 1,000×g for 5min. The casings were remov ed after centrifugation. T he skinless sausages were placed on a sieve with a mesh size of 5mm to remove separated fluid. The yield was obtained by dividing the weight of the sausage after removal of fluid by the weight of the sausage before removal of fluid. The weight of the casing was then subtracted from the sausage weight.

11. Texture measurement

Sausages were returned to room temperature and cut into 25 mm-thick slices for texture profile analysis (TPA) using an Instron Universal Testing Machine (Model 5543; Instron Japan Co., Ltd., Kanagawa, Japan). Briefly, the sliced sausage samples were compressed twice with disk plungers (diameter, 75mm) at the compression speed of 50 mm/min, to reduce the height of the sausage sample by 50%. Resulting pressed samples were subjected to measurement of hardness, springiness, cohesiveness, and chewiness.

12. Sensory evaluation

Appearance, flavor, texture, juiciness, taste, and overall impression of sausages cooked at 70℃ for 20 min were judged by 23 volunteers (11 men and 12 women; age range, 15-55 years) using a seven-point scale (1, very bad; 2, bad; 3, fairly bad; 4, average; 5, fairly good; 6, good; 7, very good).

Results and Discussion

1. Composition, pH, color, and water holding capacity of okara

Table 3 shows the composition, pH, color and water holding capacity of okara. Okara contained a large amount of moisture (approx. 76%), and was high in protein (approx. 7%) and dietary fiber (approx. 10%). On the dry weight basis, the mean content of protein, fat, ash, and dietary fiber was approximately 28, 9, 4, and 42%, respectively, which is comparable to that of 19～38, 8～23, 3～5, and 32～58%, respectively, reported in previous studies[1),4),6),7),20),24)]. This suggests that the okara used in the present study has standard properties.

Table 3 Chemical and physical properties of okara

Moisture (%)	76.01±0.69	
Protein (%)	6.77±0.32	(28.20±0.69)[1]
Fat (%)	2.25±0.22	(9.35±0.63)[1]
Ash (%)	0.93±0.13	(3.87±0.44)[1]
Insoluble fiber (%)	8.01±0.44	(33.37±0.99)[1]
Soluble fiber (%)	2.03±0.07	(8.47±0.12)[1]
pH	6.72±0.01	
Colors L*	84.32±0.20	
a*	1.25±0.03	
b*	18.87±0.06	
WHC[2]	11.83±0.55	

Values are expressed as mean ± standard deviation (n=6)
[1]: Dry Matter
[2]: Water holding capacity

The okara suspension was close to neutral (pH 6.72). The color of okara was a pale yellowish-white with L*, a*, and b* values of 84.32, 1.25, and 18.87, respectively.

The water holding capacity was 11.83, indicating that the okara was able to absorb approximately 10 times its dry weight in water. This high water holding capacity is consistent with previously reported results[21),22),24)~26)], probably owing to the high content of dietary fiber in okara[21)].

2. Compositions of sausage samples

Compositions of sausage samples are shown in Table 4. Moisture content and dietary fiber increased and protein and fat decreased as the amount of okara was increased. The 10, 15, and 20% okara sausage samples contained significantly more moisture and significantly less fat than the control sample ($p<0.05$). Okara content-dependent differences in the content of protein and dietary fiber were significant between any two samples ($p<0.05$). On the other hand, there was no significant difference in the ash content among samples. The content of moisture, protein, fat, and ash in the lean pork meat was 71.8, 21.8, 5.1, and 1.0%, respectively, indicating that the lean pork meat contained less moisture and more protein and fat than okara. The differences in the composition of sausage samples

Table 4 Composition of sausages formulated with okara

	Rate of okara (%)				
	0 (Control)	5	10	15	20
Moisture (%)	68.03±0.93^{a}	68.75±0.94^{ab}	69.09±0.62^{b}	69.39±0.60^{b}	69.41±0.72^{b}
Protein (%)	14.99±0.43^{a}	14.20±0.43^{b}	13.59±0.27^{c}	13.00±0.26^{d}	12.53±0.30^{e}
Fat (%)	12.92±0.37^{a}	12.62±0.38^{ab}	12.47±0.25^{b}	12.34±0.24^{b}	12.32±0.29^{b}
Ash (%)	2.82±0.08^{a}	2.80±0.08^{a}	2.77±0.06^{a}	2.78±0.05^{a}	2.78±0.07^{a}
Insoluble fiber (%)	-	0.33±0.01^{d}	0.64±0.01^{c}	0.96±0.02^{b}	1.28±0.03^{a}
Soluble fiber (%)	-	0.09±0.00^{d}	0.16±0.00^{c}	0.24±0.00^{b}	0.32±0.01^{a}

All values are expressed as mean ± standard deviation (n=6)
Values with different superscripts within a row are significantly different ($p<0.05$)

can likely be attributed to the different substitution rates of lean meat with okara.

3. Morphology of sausage samples

The external appearance of sausage sample cross sections is shown in Fig. 1, and the microstructures in sausage samples are shown in Fig. 2. The control and the 5% and 10% okara sausage samples were almost externally identical and showed a smooth cross section and a clear outline. On the other hand, the sausage outline was slightly disturbed in the 15% okara sausage sample and badly disturbed in the 20% okara sausage sample. The surface of the cross section was visibly rough and uneven, and many okara granules were scattered across the surface in the 20% sample. Microstructure analysis revealed smooth gel formation by meat protein in the control sample, while a unique bee nest-like structure of okara fiber[27] was present in the okara-containing samples. The bee nest-like structures were scattered, which disturbed the smooth gel structure of the meat protein. In particular, the bee nest-like structures became prominent enough to present a coarse appearance with large voids in the 20% okara sausage sample.

4. pH, color, and yield of sausage samples

Table 5 shows pH, color parameters, and yield of sausage samples. The pH of the control samples was 6.36 and increased as the amount of added okara increased, reaching a pH of 6.48 in the 20% okara sausage sample. The pH of the control and

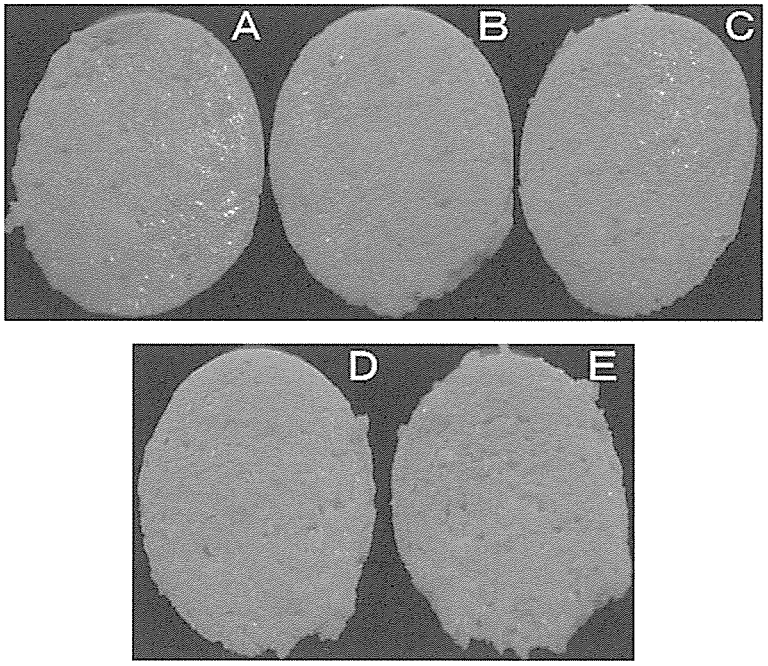

Fig. 1 Sectional images of sausages formulated with okara

A: Control; B: 5% Okara; C: 10% Okara;
D: 15% Okara; E: 20% Okara

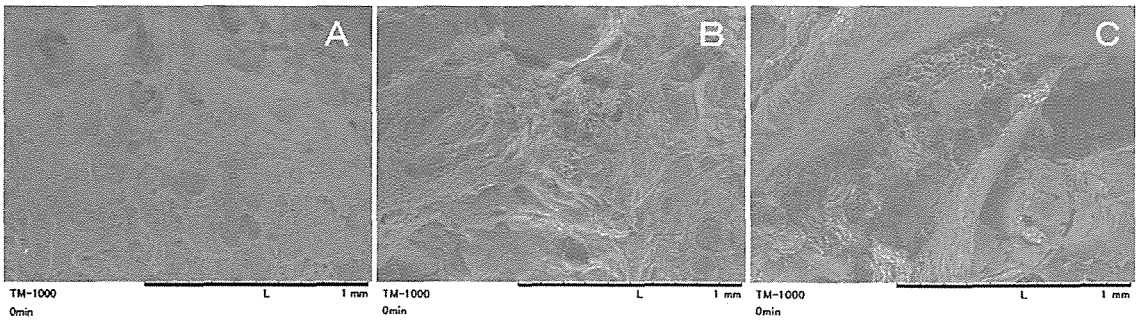

Fig. 2 Tissue morphology of sausages formulated with okara

A : Control ; B : 10% Okara ; C : 20% Okara
Black bar indicate 1 mm

Table 5 pH, color parameters, and yield rate of sausages formulated with okara

	Rate of okara (%)				
	0 (Control)	5	10	15	20
pH	6.36 ± 0.00^{d}	6.37 ± 0.02^{d}	6.41 ± 0.01^{c}	6.43 ± 0.02^{b}	6.48 ± 0.01^{a}
Color L*	69.39 ± 0.24^{d}	69.95 ± 0.33^{c}	70.29 ± 0.51^{c}	70.68 ± 0.22^{b}	71.41 ± 0.52^{a}
a*	8.53 ± 0.26^{a}	7.64 ± 0.50^{b}	6.99 ± 0.26^{c}	6.87 ± 0.33^{c}	5.99 ± 0.30^{d}
b*	8.87 ± 0.29^{d}	9.18 ± 0.24^{c}	9.56 ± 0.23^{b}	10.03 ± 0.39^{a}	10.76 ± 0.29^{a}
Yield rate (%)	96.85 ± 0.75^{b}	98.37 ± 0.29^{a}	98.62 ± 0.39^{a}	98.73 ± 0.33^{a}	98.77 ± 0.49^{a}

All values are expressed as mean ± standard deviation (n=6)
Values with different superscripts within a row are significantly different ($p<0.05$)

that of the 5% okara sausage sample were not significantly different, but both of the pH values were significantly different from the pH of the 10, 15, and 20% okara samples ($p<0.05$). The pH of the 15% okara sausage sample was significantly higher than that of the 10% okara sausage sample, while significantly lower than the pH of the 20% okara sausage sample ($p<0.05$). The cured meat contained ascorbic acid and thus its pH was lower in the control sample (6.36) than in okara (6.72). It was considered that the addition of okara skewed the pH to a higher value.

L* and b* increased while a* decreased as the okara content increased in the sausage sample, because the yellowish white area containing okara increased while the red area containing lean meat decreased. However, the color of the sausage sample was not a pure subtractive mixture of the colors of lean pork meat and okara. The color of the areas other than the scattered okara-rich areas in the okara-containing sausage samples was similar to that of the control sample. Scattered okara-rich areas were not noticeable in the 5 and 10% okara sausage samples. Thus, these two okara-containing samples were not distinguishable in color from the control sample by the naked eye, despite their significantly different spectrophotometry results compared with the control results ($p<0.05$). On the other hand, okara-rich areas were prominent in the 15 and 20% okara sausage samples, and these samples were clearly distinguishable from the control sample with the naked eye.

The yield of the control sample was 96.85%, indicating a small loss of drip. The drip loss was almost absent in the 5% okara sausage sample, and its yield was significantly higher (98.37%) than the yield of the control sample ($p<0.05$). The yield was further slightly improved as the okara content increased, but the differences in the yields among the four okara-containing sausage samples were not significant. These results suggested that an okara content of 5% is sufficient to increase yield. As shown in Table 3, okara has a high water holding capacity, suggesting that a drip was adsorbed by the okara fiber structure, resulting in prevention of drip loss, an in turn, in high yields of the sausages supplemented with okara.

Okara content-dependent changes in pH, color, and yield of the sausage samples were similar to those of beef patty samples supplemented with

okara shown by SADETTIN *et al*[22),24)].

5. Texture of sausage samples

Table 6 shows texture changes in sausages containing okara. Hardness and chewiness values were not significantly different between the control and the 5% okara sausage sample but were significantly reduced ($p<0.05$) in the 10%, 15%, and 20% okara sausage samples in an okara content-dependent manner. Only the 20% okara sausage sample showed significantly lower springiness than the control sample ($p<0.05$). The cohesiveness values of the control and the 5% and 10% okara sausage samples were not significantly different. On the other hand, the cohesiveness of the 15% okara sausage sample was significantly lower than that of the sausage samples containing less okara ($p<0.05$) but significantly higher than that of the 20% okara sausage samples ($p<0.05$). TPA measurements tended to decrease with a decrease in meat content, suggesting that the gel network structure of the meat protein[28)] was quantitatively decreased and also more severely disturbed by the okara fiber structure as the okara content increased. Such structural changes were most prominent, and all TPA measures were markedly reduced in the 20% okara sausage sample, indicating structural impairment.

6. Sensory evaluation

The results of sensory evaluation are shown in Table 7. Scores on the 7-point sensory scale were not significantly different among the control and the 5% and 10% okara sausage samples, and all three samples showed a mean scores of ≥ 5 for all sensory parameters. On the other hand, when the okara content exceeded 15%, texture, taste, and overall impression scores were significantly reduced as the okara content increased ($p<0.05$). The mean overall impression scores of the 15 and 20% okara sausage samples were 3.39 and 2.09, respectively, both of which were markedly lower than 4, the "average" score. Texture scores on the sensory scale appeared to correlate with TPA results. Overall impression scores were similar to texture scores, suggesting that texture is the main factor influencing the overall sensory characteristic of the okara-containing sausages prepared in this study. The mean flavor and juiciness scores of all sausage samples were >5 and not significantly different, suggesting that good flavor and juiciness were retained in okara-containing sausage samples. The okara used in this study was almost unscented and thus did not appear to interfere with the

Table 6 Texture profile analysis of sausages formulated with okara

	Rate of okara (%)				
	0 (Control)	5	10	15	20
Hardness (N)	27.32± 0.93^a	26.40± 1.64^a	23.36± 2.06^b	20.88± 1.88^c	10.93±0.83^d
Springiness (mm)	9.54± 0.21^a	9.54± 0.17^a	9.44± 0.19^a	9.36± 0.14^a	8.56±0.11^b
Cohesiveness	0.80± 0.03^a	0.79± 0.02^a	0.79± 0.03^a	0.71± 0.01^b	0.50±0.02^c
Chewiness (N)	208.16±20.05^a	198.80±17.13^a	173.45±19.86^b	138.69±12.36^c	47.06±3.94^d

All values are expressed as mean ± standard deviation (n=6)
Values with different superscripts within a row are significantly different ($p<0.05$)

Table 7 Sensory evaluation of sausages formulated with okara

	Rate of okara (%)				
	0 (Control)	5	10	15	20
Appearance	5.30±1.52^a	5.52±1.44^a	5.35±1.56^a	3.96±1.55^b	3.04±1.52^c
Flavor	5.22±1.41^a	5.26±1.39^a	5.35±1.34^a	5.30±1.36^a	5.30±1.33^a
Texture	5.39±1.23^a	5.48±1.44^a	5.22±1.44^a	3.26±1.10^b	2.09±1.04^c
Juiciness	5.57±1.20^a	5.61±1.27^a	5.61±1.23^a	5.43±1.34^a	5.39±1.27^a
Taste	5.30±1.15^a	5.52±1.16^a	5.35±1.40^a	3.83±1.37^b	2.70± 118^c
Overall	5.35±1.07^a	5.43±1.12^a	5.22±1.38^a	3.39±1.16^b	2.09±0.85^c

All values are expressed as mean ± standard deviation (n=23)
Values with different superscripts within a row are significantly different ($p<0.05$)

characteristic flavor of the sausage. In addition, it was considered that the drip absorbed in the okara structure in sausage samples was sufficiently released upon mastication.

Taken together, this study demonstrated that the addition of okara to sausage meat suppresses drip loss and improves yield. However, excessive okara in sausage meat, or insufficiency of lean pork meat, weakens the gel network structure of the meat protein and consequently impairs sausage texture. Sensory evaluation results showed that the 10% okara sausage sample, but not the 15% and 20% okara sausage samples, was acceptable, indicating that the addition of okara ($\leq 10\%$) to the final protein/fat mixture is appropriate. The dietary fiber content in the 10% okara sausage sample was 0.8%, which means that one sausage (approx. 20 g) made according to the same recipe provides a little less than 0.2g of dietary fiber. The increase in dietary fiber intake by consumption of this okara-supplemented sausage is low; however, our findings suggest that processed meat products supplemented with okara can serve as a source of dietary fiber. In addition, this study suggests that the large amount of moisture contained in okara can possibly be utilized by using frozen okara as a partial alternative to iced water to reduce the frictional h eat generated during the mincing, mixing, and blending stages of the sausage making process.

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オカラを添加したソーセージの品質について

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豆乳生産時の副産物であるオカラの有効利用と食物繊維を含んだ新規な肉製品の開発を図るため，オカラ（水分76%）を塩漬肉と置換することで5，10，15および20%添加したソーセージを製造し，その品質を検討した。その結果，オカラ添加量の増加に伴いソーセージの水分，食物繊維，pH，L*値およびb*値は増加し，タンパク質，脂質およびa*値は減少した。歩留まりはオカラを5%添加することでドリップの流出が抑制され向上した。過度なオカラ添加は肉タンパク質が形成するゲルネットワーク構造を粗くし，テクスチャー（かたさ，弾力性，凝集性および咀嚼性）は15%以上のオカラ添加で著しく低下した。オカラを5および10%添加したソーセージはオカラ無添加のものと同等の官能評価を得た。本結果から，オカラを添加することで食物繊維を含有し，保水性が高いソーセージ製造の可能性が示され，オカラの添加量は10%程度が適当であることが明らかになった。

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