

Effects of hydrocolloids on the quality characteristics of cold-cut duck meat jelly

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Competing interests

No potential conflict of interest relevant

Abstract

In this study, we examined the effects of various hydrocolloid (alginate, carrageenan, and konjac) treatments on the quality characteristics of cold-cut duck meat jelly. Seven different types of cold-cut duck meat jelly were prepared: control, without hydrocolloids; T1, 0.5% alginate; T2, 0.5% carrageenan; T3, 0.5% konjac; T4, 0.25% alginate + 0.25% carrageenan; T5, 0.25% carrageenan + 0.25% konjac; and T6, 0.25% alginate + 0.25% konjac. The pH and moisture content of the cold-cut duck meat jelly with hydrocolloids was higher ($p < 0.05$) than that of the control. The highest lightness value was recorded for T4 and T6 ($p < 0.05$), and the hardness was lower ($p < 0.05$) in the meat jelly with hydrocolloids than in the control, except for T2 and T5. The springiness of the meat jelly was the highest ($p < 0.05$) in T1 and T4. The onset, peak, and end temperatures were the lowest ($p < 0.05$) in the control. The highest appearance score of the meat jelly was observed in T6, and its overall acceptability was higher ($p < 0.05$) than that of the control, indicating that, of all the treatments, 0.25% alginate + 0.25% konjac yielded the most desirable results. Thus, the combined use of duck skin and gelatin with alginate and konjac is potentially applicable for the development of new cold-cut duck meat products.

Keywords: Duck meat, Jelly, Cold-cut, Alginate, Carrageenan, Konjac

INTRODUCTION

Globally, duck meat consumption accounts for ~4.53 million tons per annum [1], and duck meat consumption in Korea has increased consistently in recent years. Duck meat is not only highly preferred by consumers, but also it contains higher levels of unsaturated fat acids, iron, and niacin and lower levels of cholesterol and saturated fat compared to other meats [2,3]. According to Song et al. [4], the nutritional characteristics of duck meat include omega-6 fatty acid, oleic acid, and excellent quality protein contents with considerable levels of essential amino acids. Although nutritionally superior, research on the development of duck meat product is limited, as most meat products are processed from pork or beef.

Meat jelly is an original cold-cut meat product [5] and is usually made from gelatin-rich meat by-products and lean meat [6], including brawn, sülze, and head cheese [7]. Meat jellies are value-add-

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Availability of data and material

Upon reasonable request, the datasets of this study can be available from the corresponding author.

Authors' contributions

Conceptualization: Kim TK, Kim HW, Choi YS.
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ed meat products industrially processed to increase the quality of meat by-product, which otherwise has low acceptability or market value. Meanwhile, since meat jelly is a one of the restructured meat products, it is necessary to improve its binding ability and sensorial texture properties using a binder or gelling agents [5]. Texture is an important quality indicator that determines the purchase decision of meat jellies; hence, the use of gelling agent including hydrocolloids has been proposed to improve the textural quality of meat jelly.

Hydrocolloids enhance the textural properties and water-binding capacity of meat products and are generally useful in processed meat products [8–10]. According to Kim et al. [11], gel viscosity is increased by hydrocolloids which hydrated with water and gel formation also enhanced. With this ability, it is necessary to investigate the quality of combining processed meat products with hydrocolloids, such as alginate, carrageenan, and konjac. Alginate can also enhance the water absorption ability and physical properties of meat products [12]. Carrageenan generally forms gels and also improves water absorption ability in meat products [13]. Konjac is well known to strengthen the water binding ability of meat products [14]. Thus, it is well known that hydrocolloids enhance water retention and texture in meat products [15,16]. However, the synergistic effect of combining hydrocolloids with meat jelly was not studied.

Therefore, the quality properties of meat jelly alone or in combination with various hydrocolloids toward improving the quality of duck meat jelly were investigated and generating basic information for the development of new cold-cut duck products.

MATERIALS AND METHODS

Meat jelly

Cold-cut duck meat jelly was manufactured as described by Kim et al. [5]. Fresh duck breast and skin were purchased from Farm Duck (Korea), and duck skin used to extract gelatin according to method of Kim et al. [3]. A total of seven different duck meat jellies were then manufactured; the formulation of each sample is described in Table 1. The duck breast was marinated in 1.5% salt and then incubated at 4°C for 24 hr. The marinated duck breast and skin were cooked at 75°C for 30

Table 1. The formulation (%) of the cold-cut duck meat jelly manufactured with hydrocolloids

	Control	T1	T2	T3	T4	T5	T6
Duck breast	50	50	50	50	50	50	50
Duck skin	20	20	20	20	20	20	20
Water	25	25	25	25	25	25	25
Duck gelatin	5	5	5	5	5	5	5
Subtotal	100	100	100	100	100	100	100
Alginate	-	0.5	-	-	0.25	-	0.25
Caragenan	-	-	0.5	-	0.25	0.25	-
Konjac	-	-	-	0.5	-	0.25	0.25
Salt	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Phosphate	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Sugar	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Garlic	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Black pepper	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Lemon juice	1.0	1.0	1.0	1.0	1.0	1.0	1.0

Control, without hydrocolloid; T1, 0.5% alginate; T2, 0.5% carrageenan; T3, 0.5% konjac; T4, 0.25% alginate + 0.25% carrageenan; T5, 0.25% carrageenan + 0.25% konjac; T6, 0.25% alginate + 0.25% konjac.

min, respectively, then after they cut using an Nr-963009 silent cutter (Scharfen, Witten, Germany) within three rotation times, they were blended with gelatin from duck skin, water, and ingredients. The control duck meat jelly was formulated without hydrocolloids. The experimental duck meat jelly was formulated with hydrocolloids as follows: T1, 0.5% alginate; T2, 0.5% carrageenan, T3, 0.5% konjac; T4, 0.25% alginate + 0.25% carrageenan; T5, 0.25% carrageenan + 0.25% konjac; and T6, 0.25% alginate + 0.25% konjac. Each sample was stuffed into 25 Ø PVCD (polyvinylidene chloride) casings using a stuffer. Stuffed duck meat jelly were heated at 85°C for 40 min, and then cooled at 10°C for 24 hr until gelation. The final cold-cut duck meat jelly was stored at 4°C, and the quality characteristics were analyzed within 2 days. The process was carried out three times for each 3 kg batch.

pH

The pH of a homogenate prepared with the cold-cut duck meat jelly sample (5 g) and deionized water (20 mL) were determined by a pH meter [17].

Color

The colorimeter parameters of each cold-cut duck meat jelly was determined. The light source of colorimeter (CR-410, Minolta, Osaka, Japan) were illuminate C and a calibrate plate ($L^* = +97.83$, $a^* = -0.43$, $b^* = +1.98$) was used according to the manufacturer's instructions [18].

Texture profile analysis (TPA)

A texture analyzer (TA-XTplus, Stable Micro Systems, Surrey, UK) was used to estimate TPA. The each cold-cut duck meat jelly sample cut into $2.0 \times 2.0 \times 2.0 \text{ cm}^3$. TPA was performed under the following conditions: pre-test speed (2.0 mm/s), force (5 g), maximum load (2 kg), distance (30.0 mm), head speed (2.0 mm/s), and post-test speed (5.0 mm/s) [19].

Proximate composition

Proximate compositions of the cold-cut duck meat jelly samples were analyzed using the AOAC methodology [20]. Moisture, protein, fat, and ash contents were determined by method of AOAC 950.46B, 981.10, 960.69, and 920.153 using a drying oven, the Kjeldahl method, the Soxhlet method, and a muffle furnace respectively.

Differential scanning calorimetry (DSC)

DSC was performed on DSC 4000 furnace (PerkinElmer, Waltham, MA, USA). Samples (20 µg) were placed in aluminium pans and an empty pan was used as reference. A temperature range was 10°C–120°C and heated at a rate of 5°C/min. Pyris data analysis software was used to calculate the data displayed as onset temperature (T_o), peak temperature (T_p), end temperature (T_c), and changes in enthalpy (dH) [21].

Sensory evaluation

The sensory evaluations were conducted on each cold-cut duck meat jelly sample by a sensory panelist. A 13-man panel who were researchers from Korea Food Research Institute (KFRI) were trained to evaluate the cold-cut duck meat jelly. Each meat jelly was cut into $6.0 \times 3.0 \text{ cm}^2$ (diameter \times length) and assessed in terms of appearance, chewiness, tenderness, off-flavor, and overall acceptability using the Hedonic test (9-point descriptive scale, 1 = extremely undesirable, 9 = extremely desirable) with randomized three-digit number under fluorescent lighting [22].

Statistical analysis

All experimental data were analysed via SPSS Ver. 20.0 (SPSS, USA). One-way ANOVA was conducted to determine significant differences ($p < 0.05$) among the treated groups with a completely randomized design, and Duncan's multiple range tests to analyse the quality of the cold-cut duck meat jelly.

RESULTS AND DISCUSSION

pH and color

The pH and color values of the cold-cut duck meat jelly combined with alginate, carrageenan, and konjac alone or in combination are presented in Table 2. The pH values of the meat jelly combined with hydrocolloids were higher than that of the meat jelly without hydrocolloids ($p < 0.05$) except for T5, and was the highest when combined with alginate ($p < 0.05$). In the present study, the pH of 0.5% alginate, 0.5% carrageenan, and 0.5% konjac were 6.88, 6.98, and 6.43, respectively (data not shown). These pH values of hydrocolloids may increase the pH of meat jelly. These results agree with previous study that the highest pH for restructured duck ham was observed when formulated with 1% alginate compared with various hydrocolloids [23]. Park et al. [24] confirmed a change in the pH of processed pork products with the addition of hydrocolloids. Thus, the addition of hydrocolloids might have a significant effect on the pH of cold-cut duck meat jelly.

The color values of the cold-cut duck meat jelly with hydrocolloids was found to be significantly different from that of the control ($p < 0.05$). The combined meat jelly samples with 0.25% alginate + 0.25% carrageenan and 0.25% alginate + 0.25% konjac had the highest lightness values ($p < 0.05$), and treatment with 0.5% alginate had the highest values for redness and yellowness ($p < 0.05$). The restructured ham with 0.25% alginate + 0.25% konjac also had the highest lightness value, while the redness and yellowness values did not differ significantly among the hams added with alginate, alginate + konjac, and alginate + carrageenan [23]. These changes in the lightness values might be due to the changed gelatin level of duck meat jelly by hydrocolloid, while the gelatin levels did not significantly influence redness and yellowness values according to previous studies [5,23]. In this study, the color indices of cold-cut duck meat jelly were influenced by combination with different hydrocolloids.

Texture profile analysis

Texture results of cold-cut duck meat jelly combined with alginate, carrageenan, and konjac are provided in Table 3. The hardness of the meat jelly with hydrocolloids was lower ($p < 0.05$) than that of the control, except for T2 (0.5% carrageenan) and T5 (0.25% carrageenan + 0.25% konjac), possibly due to the increased binding capacity of carrageenan. The springiness of the meat jelly was the highest ($p < 0.05$) for T1 (0.5% alginate) and T4 (0.25% alginate + 0.25% carrageenan). The highest

Table 2. Effect of hydrocolloids on pH and color of the cold-cut duck meat jelly

Treatments	Control	T1	T2	T3	T4	T5	T6
pH	6.24 ± 0.02 ^d	6.30 ± 0.01 ^a	6.26 ± 0.01 ^c	6.26 ± 0.02 ^c	6.29 ± 0.01 ^{ab}	6.25 ± 0.01 ^{cd}	6.27 ± 0.02 ^{bc}
CIE L*	67.00 ± 0.61 ^c	68.37 ± 0.53 ^b	67.13 ± 0.52 ^c	67.28 ± 0.27 ^c	69.24 ± 0.23 ^a	68.33 ± 0.44 ^b	69.01 ± 0.42 ^a
CIE a*	4.08 ± 0.30 ^b	4.89 ± 0.58 ^a	2.79 ± 0.18 ^d	2.78 ± 0.18 ^d	4.13 ± 0.19 ^b	3.11 ± 0.12 ^{cd}	3.15 ± 0.13 ^c
CIE b*	13.59 ± 0.52 ^{ab}	13.82 ± 0.37 ^a	11.98 ± 0.31 ^e	12.4 ± 0.23 ^{de}	13.93 ± 0.75 ^a	12.69 ± 0.49 ^{cd}	13.08 ± 0.32 ^{bc}

Mean ± standard deviation was presented with three replicates.

^{a-c}Different small letter in the same row means significant differences ($p < 0.05$).

Control, without hydrocolloid; T1, 0.5% alginate; T2, 0.5% carrageenan; T3, 0.5% konjac; T4, 0.25% alginate + 0.25% carrageenan; T5, 0.25% carrageenan + 0.25% konjac; T6, 0.25% alginate + 0.25% konjac.

Table 3. Effect of hydrocolloids on texture profile analysis of the cold-cut duck meat jelly

Treatments	Control	T1	T2	T3	T4	T5	T6
Hardness (kg)	0.22 ± 0.03 ^a	0.07 ± 0.02 ^d	0.20 ± 0.03 ^a	0.13 ± 0.02 ^c	0.05 ± 0.03 ^d	0.21 ± 0.04 ^a	0.16 ± 0.01 ^b
Springiness	0.49 ± 0.10 ^d	0.96 ± 0.01 ^a	0.32 ± 0.03 ^e	0.73 ± 0.18 ^b	0.92 ± 0.07 ^a	0.63 ± 0.07 ^{bc}	0.54 ± 0.15 ^{cd}
Cohesiveness	0.19 ± 0.02 ^e	0.65 ± 0.04 ^a	0.18 ± 0.01 ^e	0.34 ± 0.05 ^c	0.58 ± 0.06 ^b	0.24 ± 0.01 ^d	0.27 ± 0.03 ^d
Gumminess (kg)	0.04 ± 0.01 ^{ab}	0.04 ± 0.01 ^{ab}	0.04 ± 0.01 ^b	0.05 ± 0.01 ^a	0.03 ± 0.01 ^c	0.05 ± 0.01 ^a	0.04 ± 0.01 ^{ab}
Chewiness (kg)	0.02 ± 0.01 ^d	0.04 ± 0.01 ^a	0.01 ± 0.00 ^e	0.03 ± 0.01 ^{ab}	0.02 ± 0.00 ^{cd}	0.03 ± 0.01 ^{bc}	0.02 ± 0.01 ^{cd}

Mean ± standard deviation was presented with three replicates.

^{a-e}Different small letter in the same row means significant differences ($p < 0.05$).

Control, without hydrocolloid; T1, 0.5% alginate; T2, 0.5% carrageenan; T3, 0.5% konjac; T4, 0.25% alginate + 0.25% carrageenan; T5, 0.25% carrageenan + 0.25% konjac; T6, 0.25% alginate + 0.25% konjac.

($p < 0.05$) meat jelly cohesiveness and chewiness was recorded for T1, and gumminess for T3 (0.5% konjac) and T5. Kim et al. [23] reported that hardness, springiness, cohesiveness, gumminess, and chewiness values of duck ham with hydrocolloids (alginate, konjac, and carrageenan) were lower than that of the control, which was attributed to the increased water holding and retention capacity of duck ham when combined with hydrocolloids. These results showed similar to ours, as the duck ham with 1% alginate displayed the lowest hardness. From the previous study [23], we expected that adding hydrocolloids to meat jelly could increase water binding capacity, and which resulted in high moisture content and the lower hardness. However, although the addition of alginate (T1), carrageenan (T2), and combination of carrageenan and konjac (T5) increase the moisture content of meat jelly (Table 2), only T1 showed the lowest hardness (Table 3). As mentioned above, hardness of T2 and T5 were not significantly different from that of control. These results demonstrated that texture properties of meat jelly could be differentiated depending on the type and the amount of added hydrocolloids. Thus, desired textural properties can be obtained by using proper hydrocolloid sources that is considered suitable for the purpose.

Proximate composition

Values representing the proximate composition of the cold-cut duck meat jelly with alginate, carrageenan, and konjac are shown in Table 4. The moisture content was higher ($p < 0.05$) for the meat jelly with hydrocolloids than the control, likely due to the enhanced water binding and holding capacity conferred by the hydrocolloid [25]. The protein, fat, and ash contents were not ($p > 0.05$) different between the control and any of the hydrocolloid added samples. The moisture content of restructured meat products with hydrocolloids was higher than non-treated restructured ham [23]. Several studies have shown that the addition of hydrocolloids to meat products tends to increase moisture content due to the water retention capacity of hydrocolloids [23,26,27].

Table 4. Effect of hydrocolloids on proximate composition (%) of the cold-cut duck meat jelly

Treatments	Control	T1	T2	T3	T4	T5	T6
Moisture content	76.19 ± 0.19 ^c	78.06 ± 0.38 ^a	78.47 ± 0.25 ^a	77.92 ± 0.34 ^b	77.93 ± 0.46 ^b	78.10 ± 0.03 ^a	77.89 ± 0.15 ^b
Protein content	11.31 ± 0.45	11.29 ± 1.13	11.06 ± 0.32	11.04 ± 0.08	11.1 ± 0.27	11.25 ± 0.86	10.14 ± 0.45
Fat content	3.86 ± 0.68	3.61 ± 0.72	3.51 ± 0.64	3.90 ± 0.28	3.97 ± 0.64	3.96 ± 0.57	3.51 ± 0.14
Ash content	2.17 ± 0.17	2.27 ± 0.17	2.19 ± 0.27	2.13 ± 0.23	2.27 ± 0.27	2.19 ± 0.17	2.19 ± 0.26

Mean ± standard deviation was presented with three replicates.

^{a-c}Different small letter in the same row means significant differences ($p < 0.05$).

Control, without hydrocolloid; T1, 0.5% alginate; T2, 0.5% carrageenan; T3, 0.5% konjac; T4, 0.25% alginate + 0.25% carrageenan; T5, 0.25% carrageenan + 0.25% konjac; T6, 0.25% alginate + 0.25% konjac.

Differential scanning calorimetry

The thermal properties of the cold-cut duck meat jelly, as estimated by DSC, are presented in Table 5. The onset, peak, and end temperatures were the lowest ($p < 0.05$) in the control. This result suggests that the addition of hydrocolloids increased the heat stability of cold-cut duck meat jelly. The range of onset temperature is also important to show the melting temperature [28]. The heat stable characteristics of samples might be helpful in keeping the shape of meat jelly at ambient temperature. The highest onset temperature was recorded for T3, T4, and T5, and the lowest, for T1 ($p < 0.05$). Hydrocolloids increase the heat stability of food stuffs, but act differently depending on temperature [29]. Alginate is known as a cold-formed heat-stable gelling agents. Therefore, thermal stability was relatively lower for T1 than for other treatments. Furthermore, onset temperature of all treatments was $< 36^{\circ}\text{C}$, which is below the oral temperature of humans (37°C), suggesting that people can easily swallow melted meat products. Changes in enthalpy indicate the energy required to change the state of foods, and the lowest delta enthalpy value was recorded for T3, possibly due to the thermally irreversible characteristics of konjac, which might give the meat jelly a more viscous texture in the mouth [29].

Sensory properties

The effects of the cold-cut duck meat jelly samples with alginate, carrageenan, and konjac on sensory properties are observed in Table 6. There were different ($p < 0.05$) in appearance and overall acceptability. The chewiness, tenderness, and off-flavor scores were not significantly different ($p > 0.05$) among treatments with or without hydrocolloids. Cold-cut duck meat jelly sample T6 (0.25% alginate + 0.25% konjac) had the highest ($p < 0.05$) appearance score, whereas T1 (0.5% alginate) and T4 (0.25% alginate + 0.25% carrageenan) had the lowest scores. The overall acceptability of the meat jelly with 0.25% alginate + 0.25% konjac (T6) was higher ($p < 0.05$) than that of the control.

Table 5. Effect of hydrocolloids on DSC (differential scanning calorimetry) of the cold-cut duck meat jelly

Treatments	Control	T1	T2	T3	T4	T5	T6
Onset temperature	25.20 ± 0.87 ^d	25.91 ± 0.13 ^{cd}	26.00 ± 0.19 ^{cd}	28.72 ± 2.76 ^a	27.50 ± 0.08 ^{ab}	27.34 ± 0.18 ^{abc}	26.93 ± 0.43 ^{bc}
Peak temperature	32.65 ± 1.70 ^c	34.31 ± 0.18 ^b	34.99 ± 0.06 ^b	34.32 ± 2.41 ^b	36.82 ± 0.54 ^a	35.57 ± 0.18 ^{ab}	35.98 ± 0.41 ^{ab}
End temperature	42.03 ± 2.49 ^c	46.77 ± 0.64 ^a	44.21 ± 0.29 ^b	41.99 ± 2.41 ^c	46.10 ± 0.41 ^{ab}	44.30 ± 0.12 ^b	45.32 ± 1.32 ^{ab}
Delta enthalpy	0.65 ± 0.03 ^d	0.80 ± 0.08 ^{bc}	0.73 ± 0.17 ^{bcd}	0.51 ± 0.01 ^e	0.96 ± 0.07 ^a	0.71 ± 0.00 ^{cd}	0.82 ± 0.01 ^b

Mean ± standard deviation was presented with three replicates.

^{a-c}Different small letter in the same row means significant differences ($p < 0.05$).

Control, without hydrocolloid; T1, 0.5% alginate; T2, 0.5% carrageenan; T3, 0.5% konjac; T4, 0.25% alginate + 0.25% carrageenan; T5, 0.25% carrageenan + 0.25% konjac; T6, 0.25% alginate + 0.25% konjac.

Table 6. Sensory properties of the cold-cut duck meat jelly with different contents of hydrocolloids

Treatments	Control	T1	T2	T3	T4	T5	T6
Appearance	6.13 ± 0.76 ^b	2.13 ± 0.99 ^c	6.02 ± 0.87 ^b	5.75 ± 0.84 ^b	2.13 ± 0.99 ^c	5.13 ± 0.75 ^b	7.03 ± 0.91 ^a
Chewiness	7.86 ± 0.69	8.86 ± 0.38	7.83 ± 0.31	7.57 ± 0.77	8.14 ± 0.82	7.83 ± 0.71	8.14 ± 0.69
Tenderness	7.98 ± 0.97	8.52 ± 0.76	8.13 ± 1.13	8.25 ± 0.71	8.63 ± 0.74	8.25 ± 0.68	8.75 ± 0.54
Off flavor	3.63 ± 0.81	3.87 ± 0.95	3.63 ± 0.71	3.75 ± 0.89	4.02 ± 0.69	4.01 ± 0.77	3.75 ± 0.98
Overall acceptability	5.71 ± 0.85 ^b	3.88 ± 0.76 ^c	5.92 ± 0.76 ^{ab}	6.01 ± 0.93 ^{ab}	4.25 ± 0.97 ^c	5.38 ± 0.89 ^{bc}	6.59 ± 0.83 ^a

Mean ± standard deviation was presented with three replicates.

^{a-c}Different small letter in the same row means significant differences ($p < 0.05$).

Control, without hydrocolloid; T1, 0.5% alginate; T2, 0.5% carrageenan; T3, 0.5% konjac; T4, 0.25% alginate + 0.25% carrageenan; T5, 0.25% carrageenan + 0.25% konjac; T6, 0.25% alginate + 0.25% konjac.

The overall acceptability of the meat jelly seemed to be most influenced by the appearance scores. Kim et al. [5] reported that increased gelatin in meat jelly resulted in high appearance scores, and the addition of 5% gelatin indicated the highest overall acceptance scores. They suggested that this might be greatly related to the stable formation of the structure and texture of meat jelly combined with hydrocolloids. Kim et al. [23] observed that the overall acceptability of restructured meat products was low in all treatments with hydrocolloids, and only the 1.0% alginate and 0.5% alginate + 0.5% konjac treatments had high overall acceptability scores. Therefore, it seems that hydrocolloids do not have excellent sensory properties in all meat products [30], and a test of the suitability of hydrocolloids for specific products should precede its use.

In conclusion, cold-cut duck meat jelly combined with alginate, carrageenan, and konjac, had an effect on the quality properties of the cold-cut duck meat jelly. Our results revealed that 0.25% alginate and 0.25% konjac yielded best result for physicochemical and textural properties. Thus, the use of duck skin and gelatin with 0.25% alginate and 0.25% konjac is potentially applicable for the development of new cold-cut duck meat products.

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