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Effects of Wheat Fiber, Oat Fiber, and Inulin on Sensory and Physico-chemical Properties of Chinese-style Sausages

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ABSTRACT : This study introduces the addition of wheat fiber, oat fiber, and inulin to Chinese-style sausages, in amounts of 3.5% and 7%, respectively. Researchers used analysis of general composition and texture properties, and sensory evaluation to assess the influence of these three types of dietary fiber on the quality and palatability of Chinese-style sausages. Results showed that the type and amount of dietary fiber introduced did not significantly influence the general composition, color, and total plate count of sausages. However, the addition of wheat fiber and oat fiber significantly hardened the texture of Chinese-style sausages ($p<0.05$). A greater amount of dietary fiber added implied a harder texture. Added inulin did not influence the texture of Chinese-style sausages ($p>0.05$). Results of product assessment showed that, aside from sausages with 7% wheat fiber scoring less than 6 points (on a 9-point scale) in terms of overall acceptability, the other groups of Chinese-style sausages scored over 6 points. Judges preferred the sausage groups with 3.5% added oat and wheat fiber. This study demonstrates that adding fiber to Chinese-style sausages to increase the amount of dietary fiber is feasible. (**Key Words :** Wheat Fiber, Oat Fiber, Inulin, Chinese-style Sausages)

INTRODUCTION

The suggested amount of dietary fiber intake as published by the Food and Drug Administration (FDA) is 20 to 30 g daily. However, as dietary habits and dining forms change, the average individual almost never consumes enough dietary fiber. The American Association of Cereal Chemists (AACC) defines dietary fiber as the edible parts of plants or analogous carbohydrates; fiber cannot be digested and absorbed in the small intestine, but can be partially or wholly utilized for fermentation in the large intestine (AACC report, 2001). Based on differences in solubility, dietary fiber could be categorized as water-soluble and water-insoluble. Water-insoluble fiber is often used for preventing and treating colonic diseases, preventing and treating constipation and other related diseases, as well as regulating body weight (Nguyen et al., 2004). Water-soluble dietary fiber is beneficial in treating diabetes and reducing serum cholesterol and blood fat (Anderson et al., 1987; Ganji and Kies, 1996; Schulze et al., 2004). Water-soluble fiber can also reduce cardiovascular diseases (Pereira et al., 2004).

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A number of studies have evaluated the addition of dietary fiber to meat products. Piñero et al. (2008), for example, examined the effect of oat fiber on the quality of low-fat beef patties; Sáyago-Ayerdi et al. (2009) studied the effect of grape antioxidant dietary fiber on lipid oxidation in chicken hamburgers; Choi et al. (2009) utilized rice bran fiber and vegetable oils to investigate the characteristics of meat products with reduced fat emulsion. Because most studies have focused on reduction of fat, the amount of dietary fiber introduced in such studies has been limited to 3%. According to “Regulations on Nutrition Claims for Conventional Foods”, food products marked as “high fiber” must contain at least 6 g of dietary fiber for every 100 g of solid food; food products marked as “containing dietary fiber” must contain at least 3 g of dietary fiber for every 100 g of solid food.

Chinese-style sausages are a traditional meat product in Taiwan, and many Taiwanese enjoy the distinctive flavor and texture. This study experimented with adding different types of dietary fiber to Chinese-style sausages. Initial evaluation suggested that adding wheat fiber, oat fiber, and inulin yields the best results. As a result, this study added different amounts of wheat fiber, oat fiber, and inulin to Chinese-style sausages, and used analysis of general composition and texture properties, microbiological analysis, and evaluation of preference to assess the influence of added dietary fiber on the quality and palatability of Chinese-style sausages.

MATERIALS AND METHODS

Preparation of Chinese-style sausage

The sausages were manufactured according to a traditional formula for Chinese style sausage: Fresh pork ham (82%) and pork back fat (18%) were mixed with salt, sugar, spices, antioxidant, nitrite and soy protein. Fresh pork ham and pork back fat were purchased from a local meat packer. The tissues were ground with a meat chopper fitted with a plate of 20 mm diameter holes. The ground meat was packaged in plastic bags, 1.0 kg each, and stored at -18°C. Before use, the meats were maintained 20 h/0°C and then they were mixed with the condiments and commercial fiber. Seven batches were manufactured: six of them with different kinds (wheat fiber, dietary fiber content 97%; oat fiber, dietary fiber content 96%; inulin, dietary fiber content 90%) and levels (3.5 and 7%) of commercial fiber. The batch was manufactured without commercial fiber and was considered as control. The batches were curing at 5°C for 4 days then stuffed into hog casings previously humidified with water. Raw sausages were manually linked 10 cm in length and dried in a drying cabinet at 50°C for 1 h. Following drying, sausages were cooled and vacuum-packaged in plastic bags (NY/LLDPE laminated film) and stored in a refrigerator (5°C). All batches were manufactured in duplicate.

Physicochemical analyses

Moisture content was measured by the weight difference before and after oven drying at 105°C for 16 h. Crude lipid content was measured by drying the sample in a 105°C oven for 6 h and then extracting the lipid with ether in a Soxhlet extractor for 4 h. Crude protein content was measured by the Kjeldahl method (AOAC, 1984). The crude fiber was determined according to the method of Prosky et al. (1988). The water activity was read (Aqua Lab, USA) after equilibration at 25°C.

The pH of the raw sausages was measured after homogenization with distilled water at a ration of 1:10 using a pH meter (Denver Instrument, USA).

Hunter-*L*, *a*, *b* values of the raw sausages' leg muscle tissues were measured by color difference meter (Tokyo Denshoku Co., Model TC-1800 MK II, Japan). The mean of six measurements was taken for each Hunter-*L*, *a*, *b* values.

The texture profile analyses (TPA) indices of sausages were determined using a texture analyzer (Model TA-XT2 Texture Analysis, England). The conditions of texture analyzer were modified by Huang et al. (2005), pre-test speed, 3.0 mm/s; test speed, 1.0 mm/s; post-test speed, 3.0 mm/s; distance, 10.0 mm; time, 5.0 s; trigger type, auto; and trigger force, 10 g.

The total plate count of sausages were determined using 3 M Petrifilm™ Aerobic Count Plate (AOAC OMA: 986.33, 989.10, 990.12). Plates were incubated at 37°C for 48 h. Results were expressed as $\log_{10}$ CFU/g sausages.

The sensory analysis of sausages were evaluated by 20 untrained assessors selected according to their habits. Sausages were cut into slices 5 mm of thick. Samples were labelled with 3-digit random numbers and served in random order to assessors in individual booths. Assessors were instructed to cleanse their palates with water between samples. A hedonic test was carried out using 9 point scales (9 = like extremely and 1 = dislike extremely) (Meilgaard et al., 1991) in which the assessors evaluated different attributes: appearance, taste, texture, flavor, overall acceptability.

Physicochemical properties of dietary fibers

The physicochemical properties (bulk density, water-holding capacity, oil-holding capacity and swelling property) of dietary fibers were carried out using the methods as described by Chau et al. (1997). The solubility of dietary fibers were determined by Chau et al. (1999).

Statistical analysis

Data were analysed using SPSS 12.0 for one-way ANOVA. Duncan's new multiple range test was used to resolve the difference among treatment means. A value of $p<0.05$ was used to indicate significant difference. Correlation analysis was to assess the correlation of sausages' texture properties and dietary fibers' physicochemical properties.

RESULTS AND DISCUSSION

Proximate composition of Chinese-style sausages

Table 1 shows the chemical composition, water activity, and pH values of groups of Chinese-style sausages with wheat, oat, and inulin fiber added. The control group had the highest water content, at 56.76%, while the groups with different concentrations of added wheat, oat, and inulin dietary fiber had water content of 47.98-52.12%, significantly lower than the water content of the control group. The crude fat content of the different groups of sausages was 17.28-23.90%, crude protein content was 13.78-16.18%, and carbohydrate content was 8.29-14.91%. The experimental and control groups did not exhibit significant differences in crude fat content, crude protein content, or carbohydrates ($p>0.05$). Crude fiber content was 0.04-3.89%, and increased with added dietary fiber. Added inulin, however, did not increase crude fiber content. Dietary fiber content was calculated using the original fiber content of the dietary fiber powders (wheat fiber, 97%; oat

Table 1. Chemical composition, water activity and pH value of Chinese style sausages added with different kinds and levels of dietary fiber

Treatment	Batch	Moisture (%)	Crude fat (%)	Crude protein (%)	Ash (%)	Carbohydrates (%)**	Crude fiber (%)	Dietary fiber (%)***	a_w	pH value
1	Control	56.76±1.24^{a,*}	17.28±2.04^{a}	14.94±0.72^{a}	2.74±0.12^{a}	8.29±1.20^{a}	0.04±0.01^{e}	0	0.943±0.002^{a}	6.57±0.02^{a}
2	Wheat 3.5%	47.98±0.23^{c}	23.75±0.64^{a}	15.26±0.39^{a}	2.55±0.01^{b}	10.47±0.24^{a}	2.03±0.12^{c}	3.09	0.938±0.001^{ab}	6.57±0.04^{a}
3	Wheat 7%	50.29±3.39^{bc}	23.90±4.77^{a}	13.83±1.51^{a}	2.64±0.04^{ab}	9.35±3.22^{a}	3.89±0.16^{a}	5.91	0.941±0.004^{ab}	6.60±0.03^{a}
4	Oat 3.5%	51.30±0.25^{b}	23.44±2.33^{a}	13.78±0.27^{a}	2.65±0.07^{ab}	8.84±1.99^{a}	1.60±0.29^{d}	3.04	0.941±0.000^{ab}	6.62±0.05^{a}
5	Oat 7%	48.76±0.78^{c}	23.63±1.77^{a}	13.89±0.77^{a}	2.68±0.01^{ab}	11.05±0.98^{a}	3.50±0.00^{b}	5.87	0.936±0.006^{ab}	6.62±0.01^{a}
6	Inulin 3.5%	52.12±2.62^{b}	18.62±4.91^{a}	16.18±1.51^{a}	2.70±0.02^{a}	10.39±6.44^{a}	0.11±0.01^{e}	2.86	0.935±0.001^{b}	6.58±0.01^{a}
7	Inulin 7%	50.24±1.21^{bc}	18.12±1.55^{a}	14.20±0.74^{a}	2.54±0.03^{b}	14.91±0.78^{a}	0.07±0.04^{e}	5.47	0.941±0.002^{ab}	6.63±0.06^{a}

* Means with different superscript letters within the same column are significantly different at p<0.05.

** Carbohydrates (%) = 100%-moisture (%)-crude fat (%)-crude protein (%)-ash (%).

*** Values by calculation. Dietary fiber content: Wheat fiber 97%; Oat fiber 96%; Inulin 90%.

fiber, 96%; inulin, 90%), and based on the amount of powder added (3.5 or 7.0%) and mass lost (8-9%). Using this method of comparison, the dietary fiber content of the control group was 0%.

The water activity of typical Chinese-style sausages is around 0.91, but the type of additives influences water activity. Table 1 shows that the water activity of the various groups was between 0.935-0.943, indicating only minor differences between the groups. The pH values of the various groups were between 6.57-6.63, with no significant difference between the groups ($p>0.05$). These results are consistent with findings in research literature (Mendoza et al., 2001; García et al., 2002), indicating that the addition of dietary fiber does not influence the water activity and pH values of dry-fermented sausages. The results described above show that the addition of dietary fiber reduces the water activity of sausages but does not significantly influence other chemical components and color.

The color and texture properties of Chinese-style sausages

Chinese-style sausages have cured meat color due to the effects of nitrites (Cho and Bratzler, 1970; Wirth, 1986). Chinese-style sausages contain a mix of fatty and lean meats; to prevent fatty meats from interfering with the results of color testing, the portions of lean meat were selected for analysis during testing. Table 2 shows the results of determination of color. The L value of the various groups was between 32.82 and 36.90; values were between 6.49 and 7.53; b values were between 8.51 and 9.46. Differences between groups were not significant, indicating that the introduction of dietary fiber does not significantly influence the color of Chinese-style sausages. However, Fernández-Ginés et al. (2003) noted that the type and amount of fiber additives influence the L values of products.

Table 2 shows the results of analysis of texture properties after introducing different dietary fibers to Chinese-style sausages. Hardness was between 218.22 and 670.66; springiness between 0.61 and 0.69; cohesiveness between 0.38-0.46; gumminess between 83.82 and 293.76; chewiness between 54.20 and 187.77. There were significant differences between the groups in terms of texture ($p<0.05$). The addition of dietary fiber significantly influenced the texture of Chinese-style sausages. Chambers and Bowers (1993) suggested that of the characteristics of texture, hardness is the most significant factor in influencing consumer preference towards meat products, so this study primarily examined the hardness of Chinese-style sausages. The addition of wheat fiber significantly increased the hardness of Chinese-style sausages. An experiment by García et al. (2002) involving the addition of dietary fiber to dry-fermented sausages also found that the addition of wheat and oat fibers significantly increased the hardness of meat products. However, there were no significant differences in texture between the group with added inulin and the control group ($p>0.05$). These results

Table 2. The color and texture properties of Chinese style sausages added with different kinds and levels of dietary fiber

Treatment	Batch	Color			TPA				
		L	a	b	Hardness (g)	Springiness	Cohesiveness	Gumminess (g)	Chewiness (g)
1	Control	32.82±1.24^{c,*}	7.11±0.34^{b}	8.51±0.90^{b}	238.87±31.28^{c}	0.68±0.42^{a}	0.42±0.03^{ab}	99.86±6.57^{c}	67.52±8.29^{c}
2	Wheat 3.5%	34.51±1.76^{b}	7.53±0.45^{a}	8.86±1.16^{ab}	480.67±7.62^{b}	0.67±0.04^{ab}	0.44±0.02^{ab}	208.32±4.57^{b}	139.57±13.24^{b}
3	Wheat 7%	36.91±2.37^{a}	6.99±0.41^{b}	9.46±1.17^{a}	670.66±24.43^{a}	0.64±0.01^{ab}	0.44±0.00^{ab}	293.76±14.06^{a}	187.77±4.48^{a}
4	Oat 3.5%	35.43±1.57^{ab}	6.95±0.45^{b}	9.09±0.91^{ab}	388.26±26.60^{b}	0.69±0.01^{a}	0.46±0.01^{a}	176.51±6.75^{b}	121.55±4.45^{b}
5	Oat 7%	35.33±1.59^{ab}	6.49±0.37^{c}	9.01±0.63^{ab}	457.82±88.95^{b}	0.65±0.00^{ab}	0.41±0.01^{ab}	189.03±43.08^{b}	122.50±27.50^{b}
6	Inulin 3.5%	35.45±2.36^{ab}	7.04±0.68^{b}	8.85±0.61^{ab}	218.22±5.54^{c}	0.64±0.01^{ab}	0.39±0.05^{b}	83.82±9.80^{c}	54.20±4.69^{c}
7	Inulin 7%	35.41±1.14^{ab}	7.14±0.41^{b}	9.20±1.15^{ab}	225.05±59.75^{c}	0.61±0.01^{b}	0.38±0.01^{b}	85.11±18.46^{c}	52.51±12.72^{c}

* Means with different superscript letters within the same column are significantly different at p<0.05.

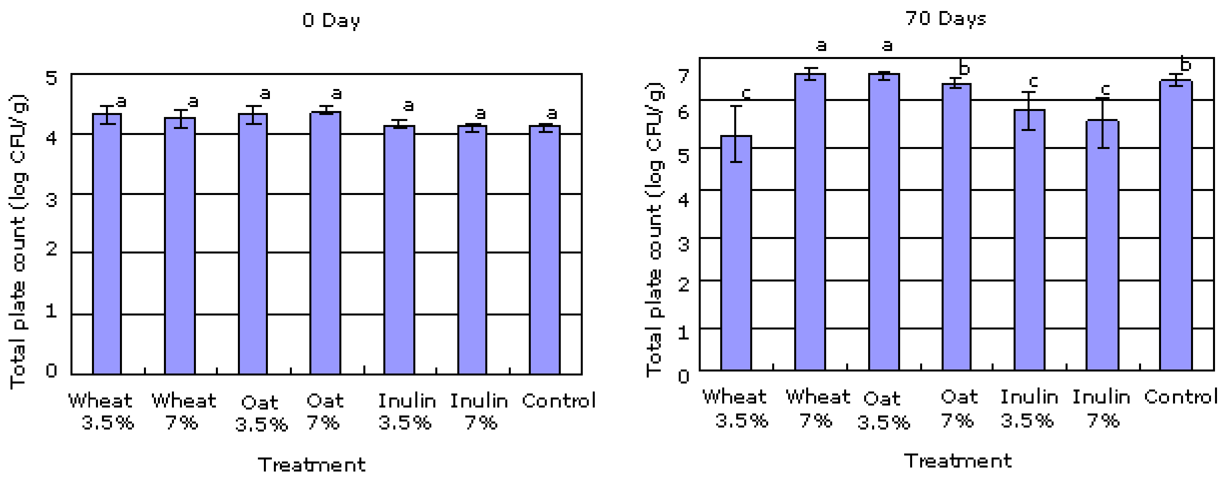

Figure 1. Microbiological counts of Chinese style sausages added with different kinds and levels of dietary fiber. [a-c] Means within a row with different letters are significantly different (p<0.05).

are also consistent with the outcomes of a study in which Mendoza et al. (2001) added inulin to dry-fermented sausage with reduced fat content. Viuda-Martos et al. (2010) found that adding 1% orange dietary fiber to the Spanish emulsified meat *mortadella* significantly increased the hardness of the product, primarily because the bonding capacity of fiber particles and the emulsified protein system were strengthened through the heating process (Viuda-Martos et al., 2009). Gumminess and chewiness were determined from the following calculations: gumminess = hardness×cohesiveness; chewiness = hardness×cohesiveness×springiness. Consequently, the resulting gumminess and chewiness of the sausages after the addition of different types of dietary fiber followed the same general trend as the hardness of the sausage.

Microbiological counts of Chinese-style sausages

Figure 1 shows the total plate counts for Chinese-style sausages. Initially, the total plate counts for the various groups were between 4.11-4.36 log CFU/g, with no significant differences between groups ($p>0.05$). The addition of dietary fiber does not significantly affect the microorganisms of Chinese-style sausages, an outcome consistent with the findings of research literature (García et al., 2002), which suggest that the addition of dietary fiber does not influence microbial growth in dry-fermented sausages with reduced fat content. *Escherichia coli* was not detected in any of the sausages. After storage at 5°C for 70 days, the total plate counts for the groups were 5.28-6.61 log CFU/g, and no *Escherichia coli* was detected, the result may be different fiber not the same from initial count and microflora. The addition of these three types of dietary fiber did not cause microbial change in Chinese-style sausages and did not influence product quality.

The sensory properties of Chinese-style sausages

Table 3 shows the results of evaluation of preference for the Chinese-style sausages. The table shows that the overall scores of the sausage groups with 3.5% added wheat and oat fiber were 7.50 and 7.67, respectively, higher than the control group. The sausage groups with added wheat and oat fiber scored approximately 7.0 for taste, texture, and flavor, and were favored most by the judges. The sausage group with 7% added wheat fiber scored lowest in sensory characteristics. The appearance and texture scores in particular for this group were only 5.11 and 5.06, respectively. The sausages in this group did not appear tightly packed, and the texture was negatively affected by

Table 3. The sensory properties of Chinese style sausages added with different kinds and levels of dietary fiber

Treatment	Batch	Appearance	Taste	Texture	Flavor	Overall
1	Control	$5.56\pm1.58^{bc,*}$	6.89 ± 1.45^{a}	6.00 ± 1.54^{b}	6.85 ± 1.53^{ab}	6.45 ± 1.33^{bc}
2	Wheat 3.5%	7.06 ± 1.39^{a}	7.44 ± 0.98^{a}	7.56 ± 1.29^{a}	7.06 ± 1.21^{ab}	7.50 ± 1.04^{ab}
3	Wheat 7%	5.11 ± 1.53^{c}	5.78 ± 1.31^{b}	5.06 ± 2.01^{c}	5.44 ± 1.76^{c}	5.50 ± 1.98^{d}
4	Oat 3.5%	6.83 ± 0.92^{a}	7.33 ± 0.91^{a}	7.56 ± 0.86^{a}	7.39 ± 1.04^{a}	7.67 ± 0.77^{a}
5	Oat 7%	6.72 ± 1.27^{a}	6.56 ± 1.42^{ab}	7.06 ± 1.26^{ab}	6.94 ± 1.51^{ab}	6.78 ± 1.00^{abc}
6	Inulin 3.5%	6.22 ± 1.26^{ab}	5.94 ± 1.43^{b}	6.39 ± 1.42^{b}	6.28 ± 1.07^{bc}	6.44 ± 1.10^{c}
7	Inulin 7%	6.11 ± 1.23^{ab}	6.56 ± 1.54^{ab}	6.39 ± 1.58^{b}	6.67 ± 1.64^{ab}	6.67 ± 1.53^{bc}

* Means with different superscript letters within the same column are significantly different at p<0.05.

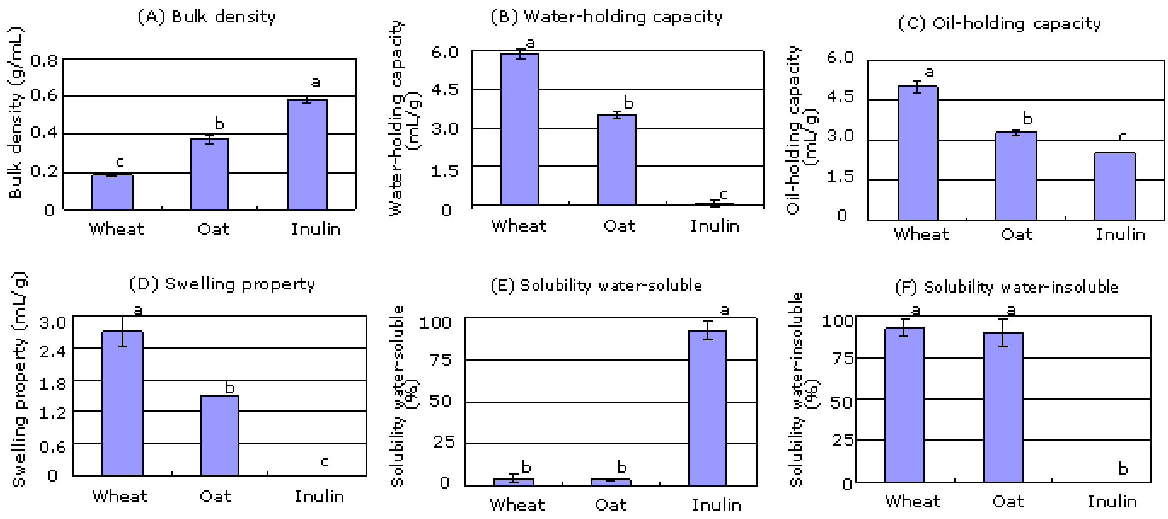

Figure 2. Physico-chemical properties of wheat, oat and inulin fiber. [a-c] Means within a row with different letters are significantly different (p<0.05).

detectable particles of powder. These results may be due to the relatively high water and oil retention of wheat fiber as well as its relatively high water insolvency (Figure 2). Wheat fiber is not suitable for addition to Chinese-style sausages at the high concentration of 7%. However, the sausage group with 7% added oat fiber scored at least 6 points, indicating no significant difference from the control group (p>0.05). These results may be due to the relatively water holding capacity and oil-holding capacity of oat fiber. Cause the sausage addition with oat fiber was not hard and juicily. The sausage groups with added inulin scored 5.94-6.67 in sensory characteristics at concentrations of both 3.5% and 7%, indicating positive preference from the judges and no significant difference from the control group (p>0.05). These results may be due to the relatively high solubility of inulin lead to the sausage groups with inulin were no significant difference from the control group in texture properties (Table 2). In conclusion, aside from the sausage group with 7% added wheat fiber, judges favored the other dietary fibers at concentrations of both 3.5% and 7%, the more fiber, the better functional.

Physico-chemical properties of wheat, oat and inulin fiber

Figure 2 shows the characteristics of volume density, water retention, oil retention, expansion, and solubility for wheat, oat, and inulin fibers. Results show that inulin had the greatest volume density (0.58 g/ml), while wheat fiber had the lowest (0.18 g/ml). Wheat fiber had the highest water retention (5.88 ml/g), followed by oat fiber (3.52 ml/g) and inulin (0.08 ml/g). Wheat fiber also had the highest oil retention (4.98 ml/g), followed by oat fiber (3.27 ml/g) and inulin (2.53 ml/g). As wheat fiber had the highest retention of water and oil, it also exhibited the greatest degree of swelling (2.7 ml/g); inulin did not exhibit swelling. Inulin had the greatest water solubility (92.6%), while wheat and oat fibers had water solubility of 4.2% and 3.4%, respectively. Wheat and oat fiber had 93.0% and 90.0% water insolubility, respectively, while inulin had 0% water insolubility. These results indicate that wheat and oat fibers are water-insoluble dietary fibers, while inulin is a water-soluble dietary fiber.

Correlation of sausages texture properties and dietary fibers physico-chemical properties

Table 4 shows the results of correlation analysis of the physical and chemical characteristics of dietary fibers and the analysis of texture of Chinese-style sausages with added dietary fiber. The table shows that for sausages with 3.5%

Table 4. Correlation of sausages' texture properties and dietary fibers' physico-chemical properties

	Texture properties				
	Hardness	Springiness	Cohesiveness	Gumminess	Chewiness
Bulk density	- 0.980 **,[1]	-0.018	0.210	-0.931 **	-0.885 **
Water-holding capacity	0.986 **	0.092	-0.112	0.957 **	0.926 **
Oil-holding capacity	0.930 **	-0.095	-0.337	0.857 **	0.795 **
Swelling property	0.971 **	0.085	-0.217	0.916 **	0.883 **
Solubility water-soluble	-0.883 **	-0.335	-0.160	-0.911 **	-0.928 **
Solubility water-insoluble	0.896 **	0.292	0.107	0.911 **	0.918 **

[1] Indicate significance at p<0.01.

added dietary fiber, hardness was negatively correlated with volume density and water solubility ($p<0.01$). Hardness was positively correlated with water retention, oil retention, swelling, and water insolubility ($p<0.01$). The correlation of gumminess and chewiness with the chemical and physical characteristics of dietary fibers followed the correlative results of hardness, because gumminess and chewiness were calculated based on hardness. Springiness and cohesiveness were not correlated with the physical and chemical characteristics of dietary fibers. To avoid increased hardness in Chinese-style sausages due to added dietary fibers, dietary fibers with low water retention, oil retention, expansion, and water insolubility should be used.

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