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TECHNO-FUNCTIONAL PROPERTIES OF THREE DIETARY FIBERS USED IN THE MEAT PROCESSING INDUSTRY

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Invited paper

Abstract: Fibers are naturally occurring compounds present in a variety of vegetables, fruits and cereals. They are used as additives in the food processing industry for not only their nutritional value, but for their versatility as a functional ingredient. This study was carried out to investigate the techno-functional characteristics of three dietary fibers namely, potato, wheat and oat, and their effect on the yield and texture of meat burgers. The findings revealed interesting functional properties for potato fiber. This fiber displayed significantly higher water (9,5 g/g) and oil (5,9 g/g) holding capacity compared to wheat and oat fibers ($p<0,05$), probably due to higher starch content and a bigger porosity of the fiber structure. Better emulsion stability of potato fiber, after cooking and frying, suggests their possible usage in comminuted meat products to enhance texture and improve cooking yield. The application of potato and oat fibers significantly improved the firmness (N) of meat burgers after frying. Overall, the findings demonstrate the potential functional and economic utility of potato fiber, as a promising source of dietary fiber.

Key words: potato fiber, wheat fiber, oat fiber, techno-functional properties, meat burgers

Introduction

Traditional sources of fibers in the diet are cereals, such as wheat, oats and barley, however nowadays nutritional fibers are obtained from all sorts of grains, vegetables and fruits *(Sze et al., 2017)*. Vegetable-based fibers are mixtures of β-glucans, amylopectin and celluloses *(Warner et al., 2001; Brewer, 2012)*. Dietary fibers have many nutraceutical benefits, that range from a digestive aid to their ability to improve colonic health and to prevent cancer (the latter is more relevant to cereal and potato fibers, as they have a larger insoluble fraction) and the lack of fibers in the diet is often associated with gastrointestinal diseases, colon cancer, increased risks of cardiovascular and metabolic diseases, including obesity and diabetes *(Schneeman, 1999; Jimenez-Colmenero et al., 2001; Fuller et al., 2016).*

In the modern food industry, fibers are of interest to food processors for not only their nutritional value, but for their versatility as a functional ingredient *(Leão, et al., 2013; Yangilar, 2013; McGill et al., 2015).* Fibers offer many desired functions, such as improving texture, appearance, moisture control and shelf life in a wide range of products like beverages, meat and dairy products, pasta, cereals and baked goods *(Mansour and Khalil, 1997; Abdul-Hamid and Luan, 2000; Paraskevopoulou et al., 2005; Montesinos-Herrero et al., 2006).*

Dietary fibers isolated from various plants have diverse functional properties namely solubility, viscosity, gel forming ability, water-binding and oil adsorption capacity, which affect final product quality and characteristics. These functional properties of fibers depend on the plant source, their structure and chemical composition *(Chau and Huang, 2003).* Much of the functionality of the various fibers comes from their ability to absorb and in some cases to bind water at two to ten times their weight. Water can serve as an economical and noncaloric addition to many products, and in its bound form may increase product shelf life. Additionally, in formulating comminuted or emulsified products, the addition of fibers can enhance the emulsion stability by retaining the fat/oil present in the formula *(Tungland and Meyer, 2002).*

The most important technological effects of fibers in the meat processing industry include: moisture and fat/oil retaining capacity, improving the stability of emulsions, substitution or reduction of fat content, increasing the yield, improving the texture and retaining the shape of the product after heat treatment, increasing storage stability and shelf-life *(Grigelmo- Miguel et al., 1999; Kim and Paik, 2012; Zinina et al., 2019).* Cereal based fibers (e.g. oat and wheat) and potato fibers are widely used in the meat processing industry. With a bland taste and a light colour, these fibers have good water retention and emulsification capacity, which make them very suitable for a wide range of meat products.

This study was carried out to investigate the techno-functional properties of potato, wheat and oat fibers in an effort to improve the understanding of the difference that these fibers have on functional properties important to meat processors. Effects on water and oil holding capacity, emulsification and texture properties were studied. Finally, the functionality of the three dietary fibers was compared in a meat burger application.

Material and Methods

Potato fibers (product name: Paselli FP) for this study were obtained from AVEBE U.A. (The Netherlands). Wheat fibers (product name: Vitacel WF200) were obtained from Rettenmaier & Sohne (Germany) and oat fibers (product name: Canadian Harvest) from Barentz International B.V. (The Netherlands). Vegetable oil used in this trial was sunflower oil (Reddy, The Netherlands), with a composition of 58% monounsaturated, 35% polyunsaturated and 7% saturated fat (according to labelled product information). Pork back-fat was obtained from the local butcher.

The basic composition of each fiber (according to product specification on the package) is given in Table 1.

Table 1. Fiber properties[1]

Composition (%)	Potato fiber	Wheat fiber	Oat fiber
Dietary fiber	70 - 75	97	94
Starch	< 25	0.8	0.4
Protein	5	0.4	-

[1] Supplier product information

For the measurement of the water holding capacity of fibers, a simple filtration method was used. A filter paper was placed into a plastic funnel and weighed (F1). 2 g of the fiber was weighed into 100 ml tap water. After stirring for 2 min, the sample was poured into the funnel and filtered into a cylinder until there was no further drip loss. The funnel, containing the filter paper and wet filtrate was then weighed (F2). All samples were measured in triplicate. The water holding capacity (WHC) was calculated as: WHC (g water/g fiber) = (F2 –F1)/2.

To compare the oil holding capacity (OHC) of three different fiber products a centrifuge method was used. 5 g of fiber and 45 g of sunflower oil were mixed in a centrifuge tube. The samples were stirred and left to rest for 5 min. They were then put into a centrifuge (Centaur 1, Beun de Ronde b.v.). After 30 min centrifugation at a speed of 2000 rpm, the supernatant was poured out and the remaining in the tube weighed (S). All samples were measured in triplicate. The amount of bounded oil was calculated as: OHC (g oil/g fiber) = S/5.

In order to compare the emulsion stability of fibers, emulsions were made under a 1:7:7 ratio (1 part fiber to 7 parts pork back fat to 7 parts water). Using a Stephan mixer (UM5, The Netherlands), the fat is first very roughly chopped under vacuum with approximately one-eighth of the water at a medium speed (1500 rpm) for 1 min. The fiber was then added and gradually the remaining water is added and further mixed at high speed (3000 rpm) for 2 min. The emulsion was poured into the 200 ml cans and pasteurized in a water bath at 75°C for 40 min, until reaching 72°C in the center of the can. The cans are then cooled with tap water before being refrigerated overnight. The cooked emulsion stability of fibers was assessed after opening the cans and described sensorially using a 5-point grading system (from 5 = no fat loss, to 1 = much fat loss). After that, each emulsion was fried in sunflower oil at ~180°C for 1 min and a similar sensorial test was conducted to describe emulsion stability after frying, using a scale from 5 = stable structure, to 1 = loss of structure. All samples were scored in triplicate.

The effect of adding different fiber on the burger yield and texture was investigated. Burgers were prepared according to the recipe given in Table 2. All the ingredients were obtained from the local store and are widely available on the market. The ingredients were mixed together and burgers of approx. 90 g were formed and pan-fried. Three different groups of burgers were made, depending on the fiber source.

Table 2. Burger formulation

Ingredient	%
Beef (15% fat)	60.5
Pork (20% fat)	15.2
Water	17.8
Salt (NaCl)	1.2
Spices and flavors	4.0
Polyphosphate (STPP)	0.3
Fiber[1]	1.0
TOTAL	100.0

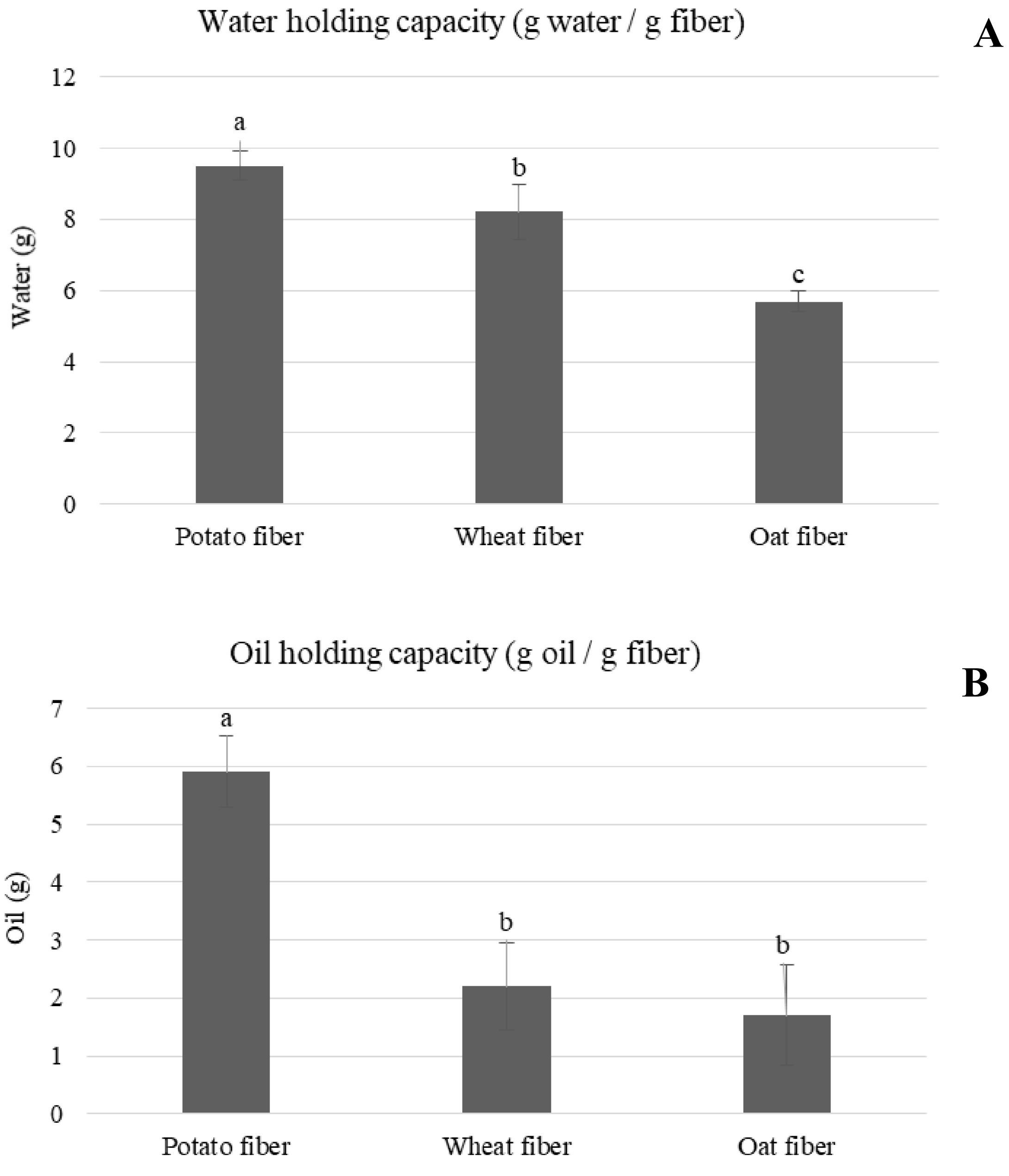
[1] Three groups were made: potato, wheat, oat

Process loss was calculated by measuring the difference in weight before and after frying the burgers, and expressed as a percentage of the initial weight. Texture measurements were performed on fried burgers using a Shimadzu EZ-SX texture analyzer (Shimadzu Corp, Japan) equipped with a 5 kg load cell and a cylindrical probe with a diameter of 36 mm. The firmness was measured as the maximum force (N) required to compress a burger sample by 50% at a speed of 1 mm/s. Nine replicate samples were tested from each group.

The results were analyzed statistically using one-way analysis of variance with the ANOVA procedure from SPSS 20.0 software (IBM SPSS Statistics, Version 20, IBM Corp, USA). Statistically significant differences between samples were defined as $p<0.05$. All the data in are expressed as means ± standard deviation.

Results and Discussion

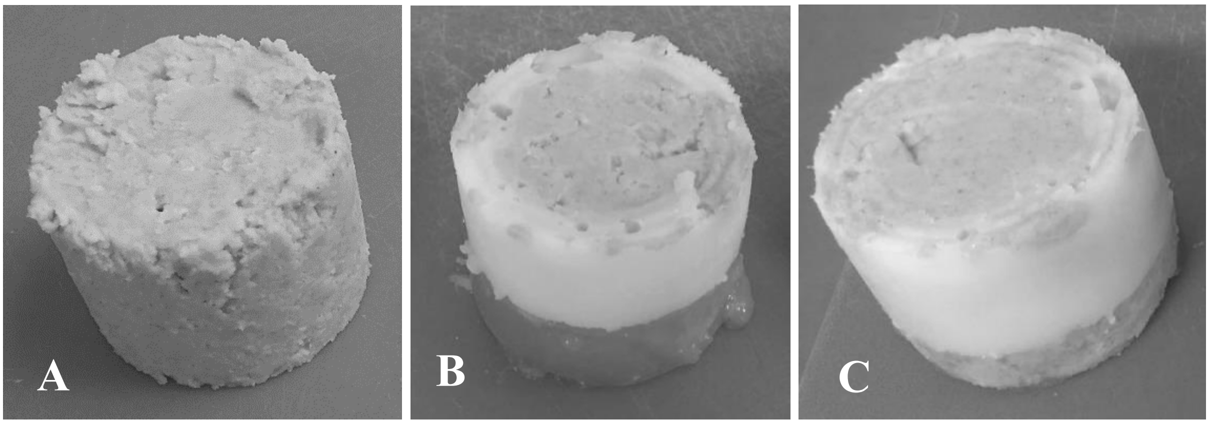
Significant differences ($p<0.05$) were observed between the WHC and OHC of the three fibers and these results are represented in Graph 1.



Graph 1. Water (A) and oil (B) holding capacity of three different fibers (different letters (a-c) denote a significant difference between means at $p<0.05$)

Potato fiber had a significantly higher water and oil holding capacity compared to wheat and oat fibers ($p<0.05$). Higher water holding capacity can be correlated with a higher starch content of potato fibers (Table 1). On the other hand, oil binding is in part related to fiber chemical composition, but is more largely a function of the porosity of the fiber structure *(Biswas et al., 2011)*. The composition differences between the three fibers could be mainly attributed to their different origins and to the different extraction procedures *(Ktari et al., 2014)*. Wheat fibers had a better water holding capacity compared to oat fibers ($p<0.05$). There was no significant difference in oil holding capacity between wheat and oat fibers. Somewhat lower water and oil holding capacity of potato fibers (6 g/g and 2g/g, respectively) was reported by *Ktari et al. (2014)*, although the authors investigated the potato fibers from a different producer (Vitacel KF500), which can explain the differences with current research.

The superior fat emulsification capacity of potato fibers is presented in Picture 1 and the sensory scores for cooked and fried emulsions are given in Table 3. Potato fibers had significantly higher scores for both attributes tested, compared to wheat and oat fibers ($p<0.05$). There were no significant differences between wheat and oat fibers in emulsion characteristics (Picture 1, Table 3). Oat fibers are often used in the production of emulsion-type products such as sausages and pâtés, as they reportedly enhance the flavor and texture *(Chang and Carpenter, 1997; García et al., 2002; Desmond and Troy, 2003; Serdaroglu, 2006; Talukder and Sharma, 2010)*. Based on the better emulsion stability of potato fibers presented in this trial, we can conclude that they can be used in higher extended emulsion-type products, compared to oat and wheat fibers.



Picture 1. Potato (A), wheat (B) and oat (C) fiber emulsions (1:7:7, fiber:fat:water) after cooking

Table 3. Cooked and fried emulsion ratings (mean ± standard deviation)[1]

Fiber	Cooked emulsion[2]	Fried emulsion[3]
Potato	4.9 ± 0.2^{a}	4.7 ± 0.3^{a}
Wheat	3.2 ± 0.0^{b}	2.2 ± 0.1^{b}
Oat	2.0 ± 0.1^{b}	1.4 ± 0.1^{b}

[1] Different letters (a-b) within the column denote a significant difference between means at $p<0.05$
[2] Scale from 5 = no fat loss, to 1 = much fat loss
[3] Scale from 5 = stable structure, to 1 = structure loss

Considerable variations in literature data can be found on different fibers effects on the cooking yield and texture of various meat products. The presence of different fibers was previously reported to induce effects ranging from no effect on cooking yield in low-fat beef burgers *(Desmond et al., 1998)* to significant improvements in cooking yield in low-fat bologna *(Claus and Hunt, 1991). Thebaudin et al. (1997)* reported that the addition of fiber seems to favor water binding and fat absorption of meat products, but the effect was depended on the fiber source. It has previously been shown that adding oat fiber to low-fat sausages can improve the cooking yield *(Hughes et al., 1997; Aleson-Carbonell et al., 2005)*. A decrease in frying loss as a result of adding oat or barley fiber to low-fat meat patties has also previously been shown *(Kumar and Sharma, 2004; Pinero et al., 2008). Besbes et al. (2008)* reported that the use of wheat dietary fibers increased cooking yield, decreased the shrinkage during frying and minimized the production costs without degradation of sensory properties of beef patties. *Desmond et al. (1998)* reported that adding oat fiber had limited effects on the yield and water holding capacity of low-fat beef burgers.

In the present trial, the process losses of the burgers made with the addition of potato fibers were significantly lower compared to wheat and oat fibers (Table 4). This can be correlated to a higher water and oil binding capacity of potato fibers (Graph 1).

Table 4. Process loss and firmness of fried burgers (mean ± standard deviation)[1]

Burger group	Process loss (%)	Firmness (N)
Potato	4.93 ± 0.74^{b}	12.71 ± 2.10^{a}
Wheat	8.72 ± 1.15^{a}	7.12 ± 1.08^{b}
Oat	10.69 ± 1.61^{a}	11.08 ± 1.54^{a}

[1] Different letters (a-b) within the column denote a significant difference between means at $p<0.05$

The difference in burger firmness (N) when the different fibers were added is presented in Table 4. When adding potato and oat fibers, the firmness of the burgers was significantly higher compared to the wheat fiber group ($p<0.05$), with no significant difference between these two. Interestingly, the higher starch content of potato compared to oat and wheat fibers (Table 1) didn't had a significant effect on lowering the firmness of the final product. Similar findings were also reported by *Petersson et al. (2014).*

Conclusion

The values recorded for the water and oil binding capacity of the three dietary fibers could be related to their origins and their processing procedures that could have significantly affected their compositions, physical structures, porosities, and particle sizes. The ability of fibers to assist in the stabilization of fat and water during the production process provides enhanced tolerances that are very important in the modern meat processing industry. The high water and oil holding capacity of the potato fibers suggest that they could be used as a functional ingredient in meat formulations to modify texture and viscosity, increase yield and improve the texture of the final product. The increased insoluble fiber content also offers a nutritional benefit for the consumer.

Tehno-funkcionalne karakteristike tri dijetalna vlakna korišćena kao aditivi u industriji mesa

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Rezime

Vlakna su prirodno prisutna u raznim vrstama povrća, voća i žitarica. Koriste se kao aditivi u prehrambenoj industriji ne samo zbog svoje nutritivne vrednosti, već i zbog svojih raznovrsnih funkcionalnih svojstava. Ovo istraživanje je sprovedeno kako bi se istražile tehno-funkcionalne karakteristike tri dijetalna vlakna, preciznije krompira, pšenice i zobi, i njihov uticaj na prinos i teksturu hamburgera. Dobijeni podaci ukazuju na zanimljiva funkcionalna svojstva vlakana krompira. Ovo vlakno je pokazalo značajno veći kapacitet vezivanja vode (9,5 g/g) i ulja (5,9 g/g) u poređenju sa vlaknima pšenice i zobi (p <0,05), verovatno zbog većeg sadržaja skroba i veća poroznosti u strukturi samih vlakana. Bolja stabilnost emulzije vlakana krompira, nakon kuvanja i prženja, sugeriše njihovu moguću upotrebu u emulgovanim mesnim proizvodima radi poboljšanja teksture i poboljšanja prinosa tokom termičke obrade. U poređenju sa pšeničnim vlaknima, primena vlakana krompira i zobi poboljšala je čvrstinu (N) hamburgera nakon prženja. Rezultati istraživanja pokazuju potencijalnu funkcionalnu upotrebljivost vlakana krompira u industriji mesa, kao obećavajućeg izvora dijetetskih vlakana.

Ključne reči: vlakna krompira, pšenična vlakna, vlakna zobi, tehno-funkcionalna svojstva, hamburger

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