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Evaluation of Resistant Starch in Crackers Incorporated with Unpeeled and Peeled Pumpkin Flour

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ABSTRACT

The Resistant Starch (RS) content of Peeled Raw Pumpkin Pulp (PRPP), Unpeeled Raw Pumpkin Pulp (URPP), Peeled Pumpkin Pulp Flour (PPPF), Unpeeled Pumpkin Pulp Flour (UPPF) and crackers incorporated with different levels of the PPPF and UPPF were investigated in this study. Results showed that URPP to have significantly higher RS content compared to PRPP. Likewise, UPPF had significantly higher RS content compared to PPPF. No significant differences were observed between crackers incorporated with different levels of PPPF. However, significantly higher RS content was found in the crackers incorporated with 15 and 20% UPPF, with the 20% UPPF crackers having high RS content. Crackers incorporated with UPPF had significantly high RS content compared to PPPF incorporated crackers with similar levels of incorporation (except for the 5% incorporation).

Key words: Resistant starch, raw pumpkin, pumpkin flour, crackers

INTRODUCTION

Developing interest in using food with high Resistant Starch (RS) content has increased. This is mainly because consumers prefer to eat food which can accomplish both nutritional functions as well as confer additional health benefits on regular consumption. Food ingredients and products which claim to posses' high RS content have carved a special niche in the food market. Hence, researchers and manufacturers in the food industry have increased their efforts to explore for innovative ingredients and alternative food products that can meet the demand of the consumers. RS includes starch and starch breakdown products which are not absorbed by the small intestine of a healthy individual and becomes a substrate for fermentation by microflora of the large intestine (EURESTA, 1993; Aparicio-Saguilana *et al*., 2007). Fermentation of RS produces Short Chain Fatty Acids (SCFAs) such as propionic acid, butyric acid and acetic acid, with 25-30% of the total SCFAs comprising of butyric acid (Weaver *et al*., 1992). RS can be found in almost all the starchy foods of plant origin. The botanical source of starch and the type of processing determines the amount of RS present in a food (Goni *et al*., 1996).

The significance of RS lies in the physiological functions of butyric acid. Butyric acid provides energy for colonic epithelial cells and inhibits malignant transformations (Weaver *et al*., 1992; Fuentes-Zaragoza *et al*., 2010). RS may also act as probiotic (Haralampu, 2000) and has been shown to play an important role in fecal bulking, increased defecation and lowering of the colonic pH (Phillips *et al*., 1995). RS may help to reduce serum cholesterol and triglycerides levels and also

may reduce post-prandial glycemic responses (De Deckere *et al.*, 1993; Garcia-Alonso *et al.*, 1999). RS is classified based on the nature of the starch and its environment in food. RS type 1 (RS1) (found in whole or partially intact seeds, legumes and unprocessed whole grains) are physically inaccessible starches that include starch trapped in cellular matrix. RS type 2 (RS2) are starches in the ungelatinized, native granular form and are usually found in unripe bananas and raw potatoes. Due to the high degree of crystallinity, RS2 are less susceptible to hydrolysis. When starchy foods are cooked and cooled, it produces a fraction of retrograded starch known as RS type 3 (RS3). RS3 is very important in food systems, as it is stable against food processing and retains its indigestibility when added as an ingredient in processed foods RS type 4 (RS4) consist of chemically modified starches and industrially processed food ingredients that are widely used as additives to improve commercially processed foods (Aparicio-Saguilana *et al.*, 2007; Sanz *et al.*, 2009).

People in Asia and Pacific countries have been reported to have a high demand for pumpkins (Emadi *et al.*, 2007). Pumpkin has received increased attention due to its nutritional value, polysaccharide content of the fruit and the oil content of the seeds (Murkovic *et al.*, 2004). Pumpkin is a good source of carotene, pectin, mineral salts, vitamins (Jun *et al.*, 2006) and other bioactive substances such as phenolic compounds and terpenoids (Crozier, 2003). Pumpkin is generally eaten when it is immature or ripe but cooking is essential prior to consumption. Pumpkin can be boiled, baked, steamed (Desai and Musmade, 1998), dried, pickled or canned (Mayor *et al.*, 2008). Pumpkin can even be processed into syrup, jam, jelly and puree (Gliemmo *et al.*, 2008). Ptitchkina *et al.* (1998) reported that pumpkin powder contains 40% cellulose, 4.3% hemicellulose and 4.3% lignin that are the main components of insoluble dietary fibre. Consumption of a high fibre diet has been reported to protect against health disorders such as diabetes mellitus, cardiovascular diseases, constipation, hemorrhoids and colon cancer (Mendeloff, 1987; Anderson *et al.*, 1994). The high fibre content of pumpkins also suggests that it may contain high amount of RS.

It is a known fact that the food processing industry requires large quantity of agricultural crops, fruits and vegetables as raw materials (Ngoc and Schnitzer, 2009). Eventually the food processing sector produces a vast amount of by-products that are often regarded as waste. The waste may include solid waste (such as plant debris, seeds, leaves, peels and husks), organic waste and waste water. Waste has been reported as the most visible environmental problem in Southeast Asian countries (Ngoc and Schnitzer, 2009). Sustainable development is a delicate balance between the human needs to improve lifestyles and well-being and preserving the natural resources and ecosystems on which we and future generations depend (Anon, 2009). Under the sustainable development concept, integrated waste management system that focuses on the methods to reduce waste at its source before entering the waste stream has been introduced in many countries. This is known as sustainable solid waste management. Through this system, any residues or waste are to be considered as potential input for a new process or product (Ngoc and Schnitzer, 2009).

In response to this, researchers in the field of food science and technology have doubled their effort for finding measures that will promote the utilization of by-products. These by-products could be used as innovative ingredients for nutritional enhancement of existing food or as raw materials for new food product development. One of the methods that have been practiced by the food industry is the utilization of fruit and vegetable peels. There are a number of studies that have reported the utilization of such peels to produce value-added food products. Apple pomace has been studied for the production of pectin which has a superior gelling property compared to citrus pectins (Kennedy *et al.*, 1999). Potato peel extract has been reported to have antioxidant properties that

are comparable to butylated hydroxyanisole (Rodriguez de Sotillo *et al*., 1994) which is a synthetic antioxidant commonly used in food. Other efforts have focused on incorporating carrot pomace into bread (Ohsawa *et al*., 1994), cakes, pickles and dressing (Ohsawa *et al*., 1995). Besides introducing novel functional ingredients and food products, ultimately the success of these studies had directly contributed towards the sustainable solid waste management system and indirectly towards sustainable development.

This study was performed to determine the RS content of both peeled and unpeeled pumpkin. The peeled and unpeeled pumpkin was also processed into respective flours that were incorporated into crackers. The aims of this study are to evaluate the RS content of peeled and unpeeled raw pumpkin pulp (PRPP and URPP), peeled and unpeeled pumpkin pulp flour (PPPF and UPPF) and crackers incorporated with different levels of the PPPF or UPPF.

MATERIALS AND METHODS

Pumpkins (*Cucurbita moschata*) were obtained from a local vegetable farm (in Penang Island, Malaysia). The wheat flour, yeast, sodium bicarbonate and salt were purchased from the Sim Company (Penang, Malaysia).

Preparation of raw pumpkin: Whole raw pumpkin (peeled or unpeeled) was cleaned under running tap water to remove dirt and soil residues. The pumpkin was cut into halves, the seeds were physically removed and the pulp was sliced and finely grated prior to determining the RS content.

Preparation of pumpkin flour: Pumpkins (peeled or unpeeled) were halved, the seeds were removed and the pulp was washed, sliced and dried overnight at 60°C in a hot air oven (AFOS Dryer, England). The dried pumpkin slices were milled into flour using a Micro Universal Bench Top Grinder (Retsch, Germany). The flour was kept chilled in an air-tight glass container.

Preparation of crackers: The crackers were prepared according to a modified formulation of water biscuit by Manley (2001) as shown in Table 1. Substitution of wheat flour with PPPF or UPPF was done at 5, 10, 15 and 20% of the total wheat flour weight.

In brief, yeast was mixed with water (25°C) and added to the other ingredients with 15 min in a Spar Mixer (kitchen Aid-KSM 900, USA) to form smooth dough. The dough was proofed for 2 h in a proofer (Bakbar Proofer, model E87, New Zealand), sheeted to a 1.0 mm thickness with a

Table 1: Formulation of the crackers

	Substitution (%)			
Ingredient (g)	5	10	15	20
All purpose flour	95.00	90.00	85.00	80.00
PPPF/UPPF	5.00	10.00	15.00	20.00
Shortening	9.64	9.64	9.64	9.64
Salt	2.02	2.02	2.02	2.02
Soda bicarbonate	0.16	0.16	0.16	0.16
Yeast	3.48	3.48	3.48	3.48
Water	50.00	50.00	50.00	50.00

sheeter (Esmach, Italy) and cut into squares measuring 3×3 cm. The pieces of dough were placed on a greased baking tray, docked using a stainless steel fork and baked in an oven (Bakbar Versatile Bench Top Turbofan Oven E 32, Australia) at 170°C for 15 min. The baked crackers were immediately cooled on a cooling rack for 20 min, stored in an air tight container and kept at room temperature in a cool, dark place.

Determination of RS content: Resistant Starch (RS) content was determined according to the method described by Goni *et al.* (1996).

Statistical analysis: All the results obtained were analyzed using the SPSS Windows software version 11.5. Data obtained were subjected to Analysis of Variance (ANOVA) test or independent samples t-test at the 5% significance level.

RESULTS AND DISCUSSION

Determination of RS content of URPP and PRPP: The results obtained of the RS content of raw pumpkin are shown in Table 2. The URPP contained significantly higher amount of RS than PRPP. This could be attributed due to the presence of the peel which is generally high in RS. RS has been regarded as a component of total dietary fibre of a food (Ranhotra, 2001; Goni *et al.*, 2009). The ability to pass the digestive tract to the colon and to impart the same physiological benefits of dietary fibre, such as increasing fecal bulk and lowering the colonic pH (Ranhotra, 2001) have been associated with the intake of food rich in RS. Jun *et al.* (2006) reported that pumpkin peel to be rich in pectin which is a type of Soluble Dietary Fibre (SDF). Therefore, the high SDF content of the pumpkin peel could be the reason for the higher RS content in the URPP. These results suggest that pumpkin should be consumed with the peel intact (after proper processing) in order to increase the sum of RS available to the body.

Determination of RS content of UPPF and PPPF: Table 3 shows the results for the RS content of peeled and unpeeled pumpkin pulp flour. As expected, the UPPF had significantly higher RS content compared to the PPPF. Similar to raw pumpkin, the presence of the peel in the UPPF could be associated with the significantly different RS content of the PPPF and the UPPF. Significantly higher RS content in the PPPF compared to the PRPP was recorded. Also, UPPF had a significantly higher RS content compared to the URPP. These observations could be attributed to the processing steps involved in making the PPPF and the UPPF that include successive heating and cooling. According to Rahman *et al.* (2007), RS3 is formed during heating and cooling of starchy products. Some of the combination effects such as drying, cooling, milling and storage during the production of the flours could have contributed to the formation of more RS3, thus accounting for the higher RS content. The results indicate that processing of pumpkin into flour (either the PPPF or the UPPF) could be advantageous, as pumpkin is known to be nutritionally superior with an enhanced RS content in the form of flour.

Table 2: Mean value of RS content (%) in raw pumpkin pulp

Sample	RS (%)
PRPP	5.45±0.40[a]
URPP	6.70±0.14[b]

Data are expressed as the Mean±standard deviation (n = 3). Mean within a column with the same superscript letter are not significant at the 5% probability level. PRPP: Peeled raw pumpkin pulp; URPP: Unpeeled raw pumpkin pulp

Table 3: Mean value of RS content (%) in different types of pumpkin flour

Sample	RS (%)
PPPF	6.41±0.42[a]
UPPF	8.82±0.79[b]
PRPP	5.45±0.40[a]
PPPF	6.41±0.42[b]
URPP	6.70±0.14[a]
UPPF	8.82±0.79[b]

Data are expressed as the Mean±standard deviation (n = 3). Mean within a column with the same superscript letter are not significant at the 5% probability level. PPPF: Peeled pumpkin pulp flour; UPPF: Unpeeled pumpkin pulp flour, PRPP: Peeled raw pumpkin pulp, PPPF: Peeled pumpkin pulp flour, URPP: Unpeeled raw pumpkin pulp, UPPF: Unpeeled pumpkin pulp flour

Table 4: Mean value of RS content (%) in crackers incorporated with different levels of peeled and unpeeled pumpkin pulp flour*

Crackers	RS (%)
% PPPF	
5	15.57±0.44[a]
10	15.24±0.28[a]
15	16.25±0.57[ab]
20	16.89±1.03[ab]
% UPPF	
5	16.62±1.47[ab]
10	17.69±0.93[bc]
15	18.77±0.66[c]
20	22.57±1.50[d]

Data are expressed as the Mean±standard deviation (n = 3). Mean within a column with the same superscript letter are not significant at the 5% probability level. PPPF: Peeled pumpkin pulp flour, UPPF: Unpeeled pumpkin pulp flour

RS content of crackers incorporated with PPPF and UPPF: The results for the RS content of the crackers incorporated with different levels of the PPPF and the UPPF are shown in Table 4. The RS quantified in the crackers might have probably originated from the wheat flour, PPPF or the UPPF. In addition, various steps involved in the cracker-making process, especially the baking and the cooling could have also contributed to the total RS content. The results showed no significant differences ($p \geq 0.05$) in the RS content of the crackers incorporated with different levels of PPPF. For the UPPF crackers, there was a significantly higher RS content observed with 15% incorporation. The significantly highest RS content was found in the crackers that were incorporated with 20% UPPF. At the same level of incorporation (except for 5%), the UPPF crackers showed significantly higher RS contents compared to the PPPF crackers. This result is probably due to the contribution of RS from the peel present in the flour. This suggests that the UPPF could be a better option for the purpose of RS enhancement in bakery products, particularly crackers, compared to the PPPF.

CONCLUSION

Results of this study showed URPP to contain significantly higher RS content compared to the PRPP, suggesting that unpeeled pumpkin could be a better source of RS than peeled pumpkin. The RS content of both the peeled and unpeeled raw pumpkin increased significantly after being processed into PPPF and UPPF. This indicates that processing pumpkins into flour could be one of the ways which could be employed to enhance RS content. The UPPF had significantly higher RS

content than the PPPF, indicating UPPF to be a better source of RS. Similarly, crackers incorporated with different levels of UPPF had significantly higher RS contents compared to the crackers with PPPF. In summary, the unpeeled pumpkin was found to be a better source for enhancing the RS contents in food and could be used or fortification, as it contained significantly higher RS content in both raw and processed form (UPPF). These results reflect the potential for utilizing pumpkin in food products without removing the peel which is commonly regarded as waste.

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