INULIN POWDER PRODUCTION FROM JERUSALEM ARTICHOKE (HELIANTHUS TUBEROSUS L.) TUBER POWDER AND ITS APPLICATION TO COMMERCIAL FOOD PRODUCTS

KRITTIYA KHUENPET1, WEERACHET JITTANIT1,4, SAROTE SIRISANSEENYAKUL2 and WARANGKANA SRICHAMNONG3

Departments of 1Food Science and Technology and 2Biotechnology, Faculty of Agro-Industry, Kasetsart University, 50 Ngam Wong Wan Road, Chatuchak, Bangkok, 10900, Thailand
3Institute of Nutrition, Mahidol University at Salaya, Nakhon Pathom, Thailand

4Corresponding author.
TEL: +66-2-562-5026;
FAX: +66-2-562-5021;
EMAIL: fagiwcj@ku.ac.th

Received for Publication January 11, 2016
Accepted for Publication April 30, 2016
doi:10.1111/jfpp.13097

ABSTRACT

The objectives of this study were to (1) determine sugars, fructo-oligosaccharides (FOS) and inulin-type fructans of Jerusalem artichoke tuber (JAT) powder and JAT inulin extract; (2) compare the chemical compositions of JAT powder and JAT inulin powder; and (3) investigate the effect of fortifying JAT inulin powder into various commercial products on the sensorial characteristics of products. The result showed that after hot water extraction, the amounts of sugars, FOS and inulin-type fructans in JAT inulin extract significantly increased \((P < 0.05)\) when compared with those of JAT powder. Protein and total dietary fiber contents in JAT inulin powder decreased around 1.6 and 5.7 times comparing with JAT powder. The result of fortifying JAT inulin powder into four commercial products such as rice porridge, instant cereal drink, ready mixed soya powder and chocolate malt mixed beverage showed that the addition of inulin lessened the sensorial scores of all products.

PRACTICAL APPLICATIONS

JAT contains health promoting compounds such as inulin and FOS which can be applied in food as dietary fiber supplement and prebiotics. The process of inulin production from JAT was developed and might be applied in the food industry. The consumption of inulin and FOS of 5–15 g/day has been reported to be beneficial to human health and showed evidence of prebiotic activity. At present, inulin was fortified in various kinds of commercial food products in Thailand. Therefore, it was interesting to fortify minimum recommended inulin daily intake of 5 g per serving size of commercial products. The sensorial evaluation results of samples fortified with JAT inulin in this study provided useful information for product development to be realized before commercially launching these JAT inulin fortified products to the market. Moreover, the JAT powder produced from grinding dried JAT could be sold as a food supplement due to its inulin and other nutrient contents.

INTRODUCTION

Inulin is a linear mixture of oligo- and/or polysaccharides consisting of D-fructose bonded by \(\beta-(2 \rightarrow 1)\) linkages that are terminated by a D-glucose molecule bonded to fructose by \(\alpha-D\)-glucopyranosyl bond (Barclay et al. 2010; Gunnarsson et al. 2014). The degree of polymerization (DP) varies from 2 to 60 units (Van Loo et al. 1995; Judprason et al. 2011) depending on various factors such as species, harvesting maturity, storage time and production conditions (Saengthongpinit and Sajjaanantakul 2005; Stanley and Nottingham 2007). Molecules with DP < 10 are so-called fructo-oligosaccharides (FOS) (Sirisanseeyakul et al. 2007).
Inulin has been reported as a dietary fiber because it is not digested or absorbed in the small intestine. In addition, it is a healthy food ingredient, alternative low-calorie sweeteners and fat substitute. Besides those functional properties, inulin and FOS have prebiotic effects by stimulating activity and growth of beneficial intestinal bacteria in the human colon (Kaur and Gupta 2002; Barclay et al. 2010; Röble et al. 2011; Gunnarsson et al. 2014).

Jerusalem artichoke (Helianthus tuberosus L.) originated in the temperate climate of North America. So far, it has been introduced and cultivated in the temperate regions around the world (Pimsaen et al. 2010). Jerusalem artichoke (JA) is used for many purposes such as human food, animal feed and the production of bioenergy and biochemical products (Li et al. 2013). A JA tuber (JAT) accumulates high levels of inulin and fructo-oligosaccharides (FOS) which are classified as fructans instead of starch for carbohydrate reserve (Marx et al. 1997). The commercial inulin powder sold in the market is mostly produced from chicory root which has inulin contents of 15–20% (López-Molina et al. 2005; Saengkanuk et al. 2011; Takeuchi and Nagashima 2011). According to Van Loo et al. (1995), JAT contains inulin in the range of 14–19%; therefore, it is also an appropriate crop for inulin production (Meijer and Mathijssen 1993; Simonovska 2000). During the past few decades, the efforts to develop the JA cultivars have occurred in Thailand (Mornkham et al. 2013); as a consequence, many varieties of JA were bred, developed and could be successfully grown in Thailand, especially in the northeast region (Vorasoot and Jogloy 2006; Tanjor et al. 2012). Judprasong et al. (2011) reported that JA grown in Thailand is a potential source of FOS and inulin-type fructans with their contents of 5.81 and 19.5 g/100 g fresh weight, respectively.

The extraction of inulin from the plant tissue is similar to extraction of sucrose from sugar beets because inulin is soluble in hot water. However, processing chicory for inulin extraction is more difficult than processing sugar beets for sugar extraction because the degradation of the inulin chain against color formation, Maillard reaction and removal of peptides and colloids have to be balanced (De Leenheer 2007). The main important factors that influence to the yield of inulin extraction include temperature, extraction time and ratio of solid to solvent (Paseephol et al. 2007; Toneli et al. 2008; Abou-Arab et al. 2011; Saengkanuk et al. 2011; Apolinário et al. 2014). The common inulin extraction methods described in the literatures are the hot water extraction with the application of various extraction temperatures and times. For instance, Laurenzo et al. (1999) grinded JAT and then applied boiling water extraction for 10–15 min. Saengthongpinit and Saijaanantakul (2005) applied hot deionized water 80°C for 1 h for inulin extraction from JAT and coagulated inulin by alcohol prior to drying. Lingyun et al. (2007) concluded that the optimal conditions for maximizing inulin extraction yield (83.6%) in conventional process were at natural pH for 20 min at 76.65°C and ratio of solvent to solid at 10.56:1 (v/w). Toneli et al. (2008) extracted inulin from dry chicory roots by hot water diffusion at an average temperature of 80 ± 2°C for 1 h with continuous stirring. Rubel et al. (2014) applied hot water extraction at 85°C for 2 h, with a solid–solvent ratio (JAT powder to distilled water) of 1:8 (w/v). The slurry was separated from the solution and then the extract was purified and decolorized before dried to be powder. Precipitation of inulin by alcohol is efficient and widely used in laboratory; however, it was deemed uneconomical and unsuitable for industrial scale application (Luque-Garcia and Luque de Castro, 2003).

Chaito et al. (2014) reported that inulin was fortified in various kinds of commercial food products (dried, liquid and semi-solid food products) in Thailand. The safety of inulin and FOS for applying in food was evaluated by many legal authorities worldwide. Inulin and FOS are officially recognized as natural food ingredients in most European countries and have a self-affirmed GRAS (generally regarded as safe) status in the U.S. (Gupta et al. 2003). The recommended daily intake value for inulin has not yet been established. It was estimated that American consumes inulin and FOS in the range of 1–4 g/day while that of European is 3–10 g/day (Van Loo et al. 1995; Niness 1999). Coussement (1999) classified inulin and FOS as soluble dietary fiber and mentioned that these substances and dietary fiber from other sources could be combined and declared as the amount of total dietary fiber for nutrition labeling purposes. The Thai recommended daily intake (Thai RDI) value and the recommended daily intake value of U.S. FDA for total dietary fiber have been specified at 25 g/day. The dietary fiber content of food could be raised by fortifying either inulin or FOS. Besides, Roberfroid (2002) concluded that inulin and oligo-fructose showed evidence of prebiotic activity if consuming them at the level of 5–15 g/day for a few weeks.

The objectives of this study were to (1) determine sugars, FOS and inulin-type fructans of JAT powder and JAT inulin extract; (2) compare the chemical compositions of JAT powder and JAT inulin powder; and (3) investigate the effect of fortifying JAT inulin powder into various commercial products on the sensorial characteristics of products.

**MATERIALS AND METHODS**

**JAT Powder Preparation**

Raw JAT samples were exposed to the preparation procedures from washing until milling to be JAT powder as the diagram shown in Fig. 1. Fresh JAT of variety JA 102 was obtained from Agro-Ecological System Research and
Development Institute, Kasetsart University (Petchaboon Research Station), Thailand. The freshly harvested JAT samples were washed and sliced to approximately 2 mm thickness. Then, the slices were immediately immersed in 0.5% w/v citric acid solution for 5 min and blanched in boiling water for 2 min. The slices were drained and transferred directly to a tray dryer setting drying temperature at 65°C. The samples were dried until reaching moisture content not over 8% in dry basis (d.b.). Then, dried JAT chips were ground to be fine powder using a Fitz mill model M5 (The Fitzpatrick Company, Elmhurst, IL) in the first milling stage and an Alpine Augsburg Pin mill type 160Z (Alpine American Corporation, Natick, MA) in the second milling step. JAT powder was stored in aluminum foil bags for further use.

**JAT Inulin Powder Production**

The procedure of JAT inulin powder production is illustrated in Fig. 1. The 300 g of JAT powder was used as a raw material for each batch of inulin powder production. Inulin was extracted from the JAT powder using hot water at temperature of 85°C for 30 min using a thermostatic chamber with the ratio of powder to water at 1:35 (w/w). Then, the extract was cooled down under ambient condition prior to the sediment separation using a basket centrifuge at 1,500 rpm with polypropylene-fabric multifil bag model F254-3 (Cannew International Trading Co., Ltd., Samutprakan, Thailand). After basket centrifugation the JAT inulin extract was concentrated to 30%Brix by boiling it on a hot plate with stirring. The concentrated solution was processed to be powder by a “NIRO” small-scale spray dryer model “Mobile Minor 2000” (GEA Process Engineering, Inc., Soeborg, Denmark) using the inlet and outlet drying air temperatures at 150 and 90°C, respectively. The collected inulin powder samples were packed and sealed in aluminum foil bags for quality determination and fortification in commercial food products. The whole production processes of JAT inulin powder were conducted in three replications.

**QUALITY DETERMINATIONS**

**Sugars, FOS and Inulin-Type Fructan Contents**

The contents of sugars, FOS and inulin-type fructans in JAT powder and JAT inulin extract samples were analyzed following the method of AOAC 997.08 (AOAC 2005). First, total sugars, FOS and inulin-type fructans were extracted from samples by applying hot water at 85 ± 2°C for 15 min in shaking water bath. FOS and inulin-type fructans in a portion of extract were hydrolyzed by inulinase. Both hot water extract samples and enzyme hydrolyzed fractions were derivatized by oximation and silylation reactions. Individual sugars which contained native fructose, glucose, sucrose and FOS (1-kestose [GF₂], nystose [GF₃] and 1F-β-fructofuranosyl nystose [GF₄]) were then defined by high-temperature gas chromatography. The sugars in the solution of inulinase hydrolyzed extract which comprised native sugars, sugars fractions from inulin and FOS (fructose and glucose) were determined using another gas chromatography (Joye and Hoebregs 2000; Judprasong et al. 2011). Amount of inulin-type fructans was calculated from the difference of the amounts of each sugar – fructose, glucose and sucrose – before and after enzyme hydrolysis as given in AOAC 997.08 (AOAC 2005; Judprasong et al. 2011). The determination of sugars, FOS and inulin-type fructan contents were done in three replicates.

**Proximate Analysis**

All of nutrient components were analyzed according to AOAC (2012) method by Technical Service Institute of Nutrition, Mahidol University, Nakhon Pathom, Thailand. JAT powder and JAT inulin powder were determined their...
moisture content by oven method (926.12), protein content by Kjeldahl method (991.20) with a factor of 6.25 for converting nitrogen to protein, fat content by acid hydrolysis method (932.06), total dietary fiber/insoluble dietary fiber/soluble dietary fiber content by enzymatic-gravimetric method (991.42, 991.43) and ash content by dry ashing method (930.30). The total carbohydrate content in the samples was calculated by difference method. The caloric value was calculated by sum of the percentages of proteins and carbohydrates multiplied by a factor of 4 (kcal/g) and total lipids multiplied by a factor of 9 (kcal/g). Proximate analysis was conducted in duplication.

Commercial Products Fortified With JAT Inulin Powder

The consumption of inulin and FOS of 5–15 g/day has been reported to be beneficial to human health and showed evidence of prebiotic activity if consuming for a few weeks (Roberfroid 2002; Judprasong et al. 2011). Thus, it was interesting to fortify minimum recommended inulin daily intake of 5 g per serving size. The amounts of JAT inulin powder which provided the recommended inulin content of 5 g was calculated as shown in Table 1.

Four commercial food products including (1) instant jasmine rice porridge with chicken flavor, (2) instant cereal drink, (3) ready-mixed soya powder and (4) instant chocolate malt mixed beverage were purchased from a supermarket in Bangkok, Thailand. Table 2 shows the amount per serving of these products and added JAT inulin weight. This amount of added JAT inulin was applied to fortify inulin content of 5 g as the minimum recommended inulin daily intake per serving size. Referring to the previous calculation, 6.94 g of JAT inulin powder contained 5 g of inulin.

Eight samples were prepared including four commercial products without JAT inulin powder (control) and those with the addition of JAT inulin powder. The sensorial qualities of all samples were evaluated in aspects of color, flavor, taste, viscosity and overall acceptability using two methods consisting of (1) the 9-point hedonic scale test (9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much, and 1 = dislike extremely) and (2) just about right scale (JAR) test, using the JAR question “is it just right, too much, or too little” to provide directional reaction to sensorial attributes (Lawless and Heymann 2010) by 30 untrained panelists who were students in the Faculty of Agro-Industry, Kasetsart University, Bangkok, Thailand. The JAR scale data was evaluated and converted to percentage.

Statistical Analysis

The software package SPSS version 12.0 was used for the analysis of variance (ANOVA) and a Duncan’s multiple range test in the statistical analysis.

RESULTS AND DISCUSSION

Sugars, FOS and Inulin-Type Fructans

The contents of sugars, FOS and inulin-type fructans in JAT powder and JAT inulin extract after basket centrifugation from three experimental runs are presented in Table 3. It appeared that the contents of fructose, glucose and sucrose in JAT powder were in the range of 0.15–2.38, 0–0.14 and 0.01–

---

**TABLE 1. VALUES OF MOISTURE CONTENT, INULIN CONTENT AND THE REQUIRED AMOUNT OF SAMPLE PER SERVING SIZE FOR JAT INULIN POWDER**

<table>
<thead>
<tr>
<th>Description</th>
<th>JAT inulin powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (g/100 g)</td>
<td>4</td>
</tr>
<tr>
<td>Inulin content (g/100 g&lt;sub&gt;dry mass&lt;/sub&gt;)</td>
<td>75</td>
</tr>
<tr>
<td>Inulin content in 1 g sample (g)*</td>
<td>0.72</td>
</tr>
<tr>
<td>Required amount of JAT powder per serving size (g)&lt;sup&gt;†&lt;/sup&gt;</td>
<td>6.94</td>
</tr>
</tbody>
</table>

*Inulin content in 1 g sample (g) = 1 g of JAT inulin powder × dry solid content (%w.b.) × inulin content in JAT inulin powder (g/100 g<sub>dry mass</sub>).

†Required amount of JAT powder per serving size (g) = 5 g of minimum recommended inulin daily intake per 1 g sample (g).

---

**TABLE 2. THE DETAIL OF FOUR COMMERCIAL FOOD PRODUCTS WITH AND WITHOUT JAT INULIN FORTIFICATION**

<table>
<thead>
<tr>
<th>Products</th>
<th>Control sample</th>
<th>Sample added with JAT inulin powder</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Amount per serving on label</td>
<td>Amount per serving on label</td>
</tr>
<tr>
<td></td>
<td>Serving size (g)</td>
<td>Added hot water (mL)</td>
</tr>
<tr>
<td>Instant porridge</td>
<td>25</td>
<td>250</td>
</tr>
<tr>
<td>Instant cereal drink</td>
<td>35</td>
<td>150</td>
</tr>
<tr>
<td>Ready-mixed soya powder</td>
<td>32</td>
<td>180</td>
</tr>
<tr>
<td>Instant chocolate malt</td>
<td>35</td>
<td>150</td>
</tr>
</tbody>
</table>
0.91 g/100 g dry mass, respectively. According to Judprasong et al. (2011), the fructose, glucose, and sucrose contents in the fresh JAT were 1.27, 0.15 and 5.67 g/100 g dry mass correspondingly. Hence, the total sugar contents of the fresh JAT investigated by Judprasong et al. (2011) were much higher than those of the JAT powder in this study. The reason is that for the process of JAT powder preparation in this study, the JAT samples were pretreated with blanching; thus, some soluble compounds such as sugars were eluted out from JAT to hot water (Takeuchi and Nagashima 2011). It also appeared that after hot water extraction, the contents of fructose, glucose and sucrose in JAT inulin extract significantly increased (P < 0.05) when compared with those of JAT powder. It should be due to the significant reduction of other impurities such as protein and insoluble fiber after extraction process.

The amount of FOS (GF2, GF3, and GF4) in JAT inulin extract was higher than JAT powder significantly. The initial contents of GF2, GF3, and GF4 were 2.54–4.74, 1.28–2.61 and 1.95–2.75 g/100 g dry mass correspondingly. After hot water extraction and basket centrifugation, the GF2 decreased to 1.84–3.71 g/100 g dry mass, GF3 and GF4 contents increased to 3.70–4.18 and 3.68–3.95 g/100 g dry mass, respectively. This result implied that the production steps applied in this study could remove some impurities and subsequently provided more purified inulin extract comparing with JAT powder.

The contents of inulin-type fructans in JAT powder and JAT inulin extract after hot water extraction were 51.86–55.14 and 73.82–79.25 g/100 g dry mass correspondingly. The level of inulin-type fructans in JAT powder determined in this study went along with the report of Stanley and Nottingham (2007), which stated that the inulin content in the fresh JAT was around 50% of dry weight. Similarly, Pandey et al. (1999) found that the dried materials of the JAT tubers contain inulin over 50%. As expected, after hot water extraction, the JAT inulin extract sample contained significantly higher proportions of FOS and inulin-type fructans than JAT powder. In other words, the extraction process could eliminate the impurities of JAT inulin extract.

### Compositions of JAT Powder and JAT Inulin Powder

The results of composition and energy determinations of JAT powder and JAT inulin powder are presented in Table 4. The energy values per 100 g of JAT powder and JAT inulin powder were 370.34 and 369.26 kcal, respectively, which are unsurprising because more than 84% d.b. of their compositions were carbohydrate that have energy value of 4 kcal/g. The moisture contents for both samples were around 3.13–3.98 g/100 g of sample. The moisture content is an important factor for powder products because it influences to the powder cohesiveness (Bhandari et al. 2013). High moisture content results in powder agglomeration and stickiness trouble during storage. JAT powder is a product made from tubers. If considering the standard of moisture content in a similar kind of powder produced from root such as cassava flour, it was found that Codex standard specifies the maximum moisture content for edible cassava flour at 13% (CAC 1989). Therefore in this study the moisture content of JAT powder is deemed safe for long term storage. The protein content of JAT powder was 11.63 g/100 g d.b. that was significantly higher than that of JAT inulin powder. According to the research of Gieslik et al. (2000, 2005), they found that JAT flour contained protein in the range from 5.5 to 12.5 g/100 g of total solids with the average value of 7.6 g/100 g. Also, Gieslik et al. (2011) claimed that in comparison with chicory root, JAT not only composes of high fructan content, but also high protein content, including essential amino acids such as lysine and methionine. After hot water extraction, the insoluble matters such as cellulose, hemicellulose and denatured protein were removed by centrifugation. Total fat in JAT powder and JAT inulin powder were not detected by acid hydrolysis method (AOAC method 932.06). According to the research of Stanley and Nottingham (2007), JAT contain little or no starch and nearly no fat. Also, Anavatmongkol et al. (2010) reported that dry powder of JAT composed of lipid for merely 0.27 ± 0.02%.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Fructose (g/100 g d.b.)</th>
<th>Glucose (g/100 g d.b.)</th>
<th>Sucrose (g/100 g d.b.)</th>
<th>Fructo-oligosaccharide (FOS) (g/100 g d.b.)</th>
<th>Inulin-type fructans (g/100 g d.b.)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>JAT powder</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batch 1</td>
<td>0.74±0.11</td>
<td>0.03±0.01</td>
<td>0.91±0.44</td>
<td>2.54±0.10</td>
<td>2.75±0.06</td>
</tr>
<tr>
<td>Batch 2</td>
<td>0.15±0.02</td>
<td>0.00±0.00</td>
<td>0.01±0.00</td>
<td>3.86±0.06</td>
<td>2.05±0.13</td>
</tr>
<tr>
<td>Batch 3</td>
<td>2.38±0.05</td>
<td>0.14±0.03</td>
<td>0.09±0.02</td>
<td>4.74±0.16</td>
<td>1.95±0.09</td>
</tr>
<tr>
<td><strong>JAT inulin extract after basket centrifugation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batch 1</td>
<td>1.61±0.12</td>
<td>0.20±0.04</td>
<td>1.30±0.10</td>
<td>3.71±0.36</td>
<td>4.18±0.16</td>
</tr>
<tr>
<td>Batch 2</td>
<td>2.04±0.04</td>
<td>0.06±0.01</td>
<td>3.53±0.19</td>
<td>2.14±0.29</td>
<td>4.03±0.05</td>
</tr>
<tr>
<td>Batch 3</td>
<td>0.58±0.29</td>
<td>0.17±0.11</td>
<td>2.08±0.70</td>
<td>1.84±0.15</td>
<td>3.70±0.41</td>
</tr>
</tbody>
</table>

Different letters in the same column indicate that values are significantly different (P < 0.05). d.b., dry basis.
TABLE 4. PROXIMATE COMPOSITIONS OF JAT POWDER AND JAT INULIN POWDER

<table>
<thead>
<tr>
<th></th>
<th>JAT powder</th>
<th>JAT inulin powder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kcal) per 100 g</td>
<td>370.34 ± 0.03</td>
<td>369.26 ± 0.25</td>
</tr>
<tr>
<td>Moisture (g/100 g)</td>
<td>3.98 b</td>
<td>3.13 b ± 0.08</td>
</tr>
<tr>
<td>Protein (N × 6.25) (g/100 g d.b.)</td>
<td>11.63 ± 0.22</td>
<td>7.14 ± 0.03</td>
</tr>
<tr>
<td>Total fat (g/100 g d.b.)</td>
<td>Not detected</td>
<td>Not detected</td>
</tr>
<tr>
<td>Total carbohydrate (g/100 g d.b.)</td>
<td>84.79 ± 0.23</td>
<td>88.16 ± 0.12</td>
</tr>
<tr>
<td>Total dietary fiber (g/100 g d.b.)</td>
<td>28.01 ± 0.67</td>
<td>4.88 ± 0.02</td>
</tr>
<tr>
<td>Soluble dietary fiber (g/100 g d.b.)</td>
<td>8.89 ± 0.52</td>
<td>4.49 ± 0.02</td>
</tr>
<tr>
<td>Insoluble dietary fiber (g/100 g d.b.)</td>
<td>19.12 ± 1.19</td>
<td>0.39 ± 0.00</td>
</tr>
<tr>
<td>Ash (g/100 g d.b.)</td>
<td>3.58 ± 0.01</td>
<td>4.70 ± 0.15</td>
</tr>
</tbody>
</table>

Different letters in the same row indicate that values are significantly different (P < 0.05).

d.b., dry basis.

JAT powder samples in this work were prepared using nonpeeling and blanching pretreatments; therefore, total dietary fiber was high in JAT powder. However, it decreased from 28.01 ± 0.67 to 4.88 ± 0.02 g/100 g d.b. for JAT inulin powder because insoluble matters were separated by centrifugation after hot water extraction. The amount of ash in JAT powder and JAT inulin powder were 3.58 ± 0.01 and 4.70 ± 0.15 g/100 g d.b., respectively. According to Jilu et al. (2003), El-Hofi (2005) and Cieślak et al. (2005), JAT have high mineral content (potassium, calcium and iron) with the range of 2.8–7.2% and be a good source for vitamins (B complex, C and β-carotene).

According to the report of Chaito et al. (2014), inulin was fortified in various kinds of commercial food products (dried, liquid and semi-solid food products) in Thailand. Therefore, in this study four commercial products, which were considered possible to fortify with the recommended level of inulin consumption per day into their serving size, were selected for JAT inulin fortification study. These four commercial food products consisted of instant jasmine rice porridge with chicken flavor, instant cereal drink, ready-mixed soya powder and instant chocolate malt mixed beverage. The sensorial results of all four samples were presented by comparing between the scores of original formula (control) and those of JAT inulin added formula. The results of sensorial quality determination using the 9-point hedonic scale test and JAR scale test were presented in Figs. 2–5.

Figure 2a shows that the addition of JAT inulin into instant jasmine rice porridge resulted in more color intensity of product. Furthermore, it appeared that the rice porridge with JAT inulin addition got the significantly lower scores in aspects of color and overall acceptability than the control sample that was not added with JAT inulin as shown in Fig. 2b. The color score of rice porridge with JAT inulin addition was only 5.27 indicating that the panelists neither like nor dislike the color of sample; in contrast, the color score of control sample was 7.67 meaning that the panelists almost like the color of sample very much. The overall acceptability score of rice porridge with JAT inulin addition was 6.27 whereas that of control sample was 7.60 indicating that the panelists significantly preferred the control sample. In the other words, the addition of JAT inulin into instant jasmine rice porridge caused the reduction of overall acceptability from almost like very much to slightly like. The sensorial scores of both samples were insignificantly different in aspects of flavor, taste and viscosity (P > 0.05) with the range of scores between 6.20 and 7.67.

The result of JAR scale test in Fig. 2c,d showed that very high percentage of panelists felt that all attributes (color, flavor, taste and viscosity) of control sample were just right whereas the lower percentage of panelists felt that all attributes (color, flavor, taste and viscosity) of sample with JAT inulin addition were just right. It must be noted that 73% of panelists had the notion that the color of rice porridge sample with JAT inulin addition was too much. According to the result, it was obvious that the addition of JAT inulin into the instant jasmine rice porridge caused the lower consumer acceptance.

Figure 3 illustrated that the sensorial evaluation results of instant cereal drink samples formulas had the similar trend to those of instant rice porridge products. Figure 3a shows that the addition of JAT inulin into instant cereal drink resulted in more color intensity of product. The instant cereal drink with JAT inulin addition got the significantly lower scores in aspects of color and overall acceptability than the control sample that was not added with JAT inulin as shown in Fig. 3b. The color score of sample with JAT inulin addition was only 5.47 indicating that the panelists neither like nor dislike the color of sample; in contrast, the color score of control sample was 7.53 meaning that the panelists almost like the color of sample very much. The overall acceptability score of sample with JAT inulin addition was 6.47 whereas that of control sample was 7.67 indicating that the panelists significantly preferred the control sample. In the other words, the addition of JAT inulin into instant cereal drink leaded to the reduction of overall acceptability from almost like very much to slightly like. The sensorial scores of both samples were insignificantly different in aspects of flavor, taste and viscosity (P > 0.05) with the range of scores between 6.73 and 7.60.

The result of JAR scale test in Fig. 3c,d showed that 100% or extremely high percentage of panelists felt that all attributes (color, flavor, taste and viscosity) of control sample were just right whereas the lower percentage of panelists felt that all attributes (color, flavor, taste and viscosity) of
sample with JAT inulin addition were just right. It must be noted that 67% of panelists felt that the color of instant cereal drink with JAT inulin addition was too much (too dark). Similarly to instant jasmine rice porridge, the addition of JAT inulin into the instant cereal drink caused the lower consumer acceptance.

Figure 4a shows that the addition of JAT inulin into ready mixed soya powder caused the color change from light yellow to light brown. Furthermore, it appeared that the ready mixed soya powder with JAT inulin addition got the significantly lower color score than the control sample as shown in Fig. 4b. The color score of ready mixed soya powder with
JAT inulin addition was only 4.87 indicating that the panelists neither like nor dislike the color of sample; in contrast, the color score of control sample was 7.33 meaning that the panelists moderately like the color of sample. The sensorial scores of both samples were insignificantly different in the other four aspects (flavor, taste, viscosity and overall acceptability) with the range of scores between 5.53 and 6.73. It was noted that the sensorial score of ready mixed soya powder was generally lower than instant jasmine rice porridge and instant cereal drink.

The result of JAR scale test in Fig. 4c,d showed that more than 50% of panelists felt that color, taste and viscosity of
control sample were just right whereas the lower percentage of panelists felt that these attributes of sample with JAT inulin addition were just right. For the flavor attribute, only 33% of panelists had the notion that the flavor of control sample was just right. The same percentage of panelists felt that the flavor of sample with JAT inulin addition was just right indicating that the addition of JAT inulin did not cause the change of sensorial acceptance in aspect of flavor. It must be noted that 100% of panelists had the notion that the color of ready mixed soya powder without JAT inulin addition was just right but 67% of panelists felt that the color of sample with JAT inulin addition was too much.
Figure 5a shows that the fortification of JAT inulin into instant chocolate malt mixed beverage did not influence to the color of product. It was because JAT inulin powder and chocolate malt had similar color which is dark brown. It appeared that the instant chocolate malt mixed beverage with JAT inulin addition got the significantly lower scores in aspects of taste and overall acceptability than the control sample as shown in Fig. 5b. The taste score of instant chocolate malt mixed beverage with JAT inulin addition was only 5.73 indicating that the panelists slightly like the taste of...
sample; in contrast, the taste score of control sample was 7.47 meaning that the panelists moderately like the taste of sample. The overall acceptability score of sample with JAT inulin addition was 6.40 whereas that of control sample was 7.40 indicating that the panelists significantly preferred the control sample. In the other words, the addition of JAT inulin into instant chocolate malt mixed beverage caused the reduction of overall acceptability from moderately like to slightly like. The sensorial scores of both samples were insignificantly different in aspects of color, flavor and viscosity \((P > 0.05)\) with the range of scores between 6.20 and 7.87.

The result of JAR scale test in Fig. 5c,d showed that high percentage of panelists felt that all attributes (color, flavor, taste and viscosity) of control sample were just right whereas the lower percentage of panelists felt flavor, taste and viscosity of sample with JAT inulin addition were just right. It must be noted that 53% of panelists had the notion that the taste of instant chocolate malt mixed beverage with JAT inulin addition was too little.

According to the result, it was obvious that the addition of JAT inulin into the all commercial food samples in this study caused the lower consumer acceptance; therefore, either product formula or JAT inulin quality especially in aspect of color must be improved before launching product to the market. The inulin powder production process especially in the evaporation and drying steps should be studied in the future research in order to lessen the color intensity of inulin powder product.

CONCLUSIONS

The production steps applied in this study could remove some impurities such as protein and insoluble dietary fiber; subsequently it provided more purified JAT inulin extract comparing with JAT powder. The result of fortifying JAT inulin into four commercial food products revealed that the improvement in either product formula or JAT inulin quality especially in aspect of color must be carried out before launching these inulin fortified products to the market. However, the development of inulin powder production from domestically grown JAT in Thailand in this work might be considered as a guideline for food industry in the region to raise the market value of local agricultural product and also replace the import of inulin powder from oversea.

ACKNOWLEDGMENT

This research was jointly funded by Kasetsart University and the Thailand Research Fund.

REFERENCES


DE LEENHEER, L. 2007. Production and use of inulin: Industrial reality with a promising future. In Carbohydrates as...
INULIN POWDER PRODUCTION AND ITS APPLICATION

K. KHUENPET ET AL.


