Gastrointestinal tolerance to an inulin-rich soluble roasted chicory extract after consumption in healthy subjects

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\textbf{A B S T R A C T}

\textbf{Objectives:} We aimed to assess in healthy subjects 1) the effect of two doses of a new naturally inulin-rich soluble chicory extract (IRSCE) on overall gastrointestinal discomfort after short-term ingestion and 2) the effect on gastrointestinal symptoms of long-term consumption of IRSCE administered at a dose compatible with its future commercial use.

\textbf{Methods:} First, the effect of IRSCE was assessed on overall gastrointestinal discomfort in a double-blind, crossover study where 18 subjects received in a randomized order a morning coffee drink including 10 g of sucrose alone (control period) or with IRSCE at two doses (8.9 and 14.0 g containing 5.0 and 7.8 g of inulin, respectively) during three consecutive 6-d periods. Second, 35 subjects were followed during a randomized, double-blind protocol where they were asked to take twice a day an instant coffee drink containing IRSCE (8.1 g/d containing inulin 5.0 g/d) or sucrose 8.1 g/d during 4 wk. The effects of the treatment on flatulence, bloating, abdominal pain, stool consistency, and number were recorded.

\textbf{Results:} In the first study a significant slight increase \((P = 0.05)\) in overall abdominal discomfort was observed with the morning coffee drink containing 7.8 g of inulin after 1 wk of consumption. In the second study, no significant differences between the IRSCE and placebo groups were evidenced with respect to gastrointestinal symptoms during the consumption period.

\textbf{Conclusion:} Short- and long-term consumptions of IRSCE, given at a daily dose containing 5 g of inulin, are well tolerated by healthy subjects.

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Introduction

Chicory roots that can contain more than 70% of inulin in their dry matter are used to extract commercial inulin and fructo-oligosaccharides; they can also be dried and roasted and used as a coffee substitute or to produce food ingredients \[1\]. Chicory root extracts have some health beneficial activities. They affect cholesterol uptake \[2\] and tumor development in mice \[3\], prevent immunotoxicity induced by ethanol \[4\], and have anti-inflammatory properties in vitro and in vivo \[5–7\]. In addition, inulin has health-promoting properties such as prebiotic activity \[8–12\], enhancement of calcium absorption \[13–15\], and weight control through the promotion of satiety \[16\].

During the conventional process of obtaining water-soluble roasted extracts from chicory roots, the roasting step induces the cleavage of inulin into fructose and glucose under the combined action of temperature and moisture. To minimize the impact of the process on inulin content, a new industrial method based on gentle roasting has been developed. It allows the production of a natural inulin-rich soluble chicory extract (IRSCE) \[17\], where the average inulin content, according to batch or harvest period, is around 60% of the weight of the dry matter, instead of an inulin content around 20% observed with the conventional method. In addition, IRSCE contains other phytochemical compounds that have shown antioxidant activities and in vitro prebiotic effect on \textit{Bifidobacterium adolescentis} (Ripoll et al., in preparation). Therefore, IRSCE provides new possibilities to formulate products such as coffee or chocolate instant drink that can provide to consumers, according to a normal consumption behavior, the minimal amount of inulin that is known to promote beneficial effects in humans, i.e., 5 to 8 g/d \[8\].

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The increase of the content of inulin in IRSCE raises the question of its gastrointestinal tolerance. Indeed, like other nondigestible carbohydrates, inulin consumption can be associated with an increase of flatulence, bloating, abdominal pain, and changes in stool consistency or frequency [18–20]. Until now, to our knowledge, no study has addressed the digestive tolerance of soluble roasted chicory extract with high inulin content and all the data published were obtained with inulin that had been purified. In this study we therefore aimed to assess in healthy subjects 1) the effect of two doses of IRSCE on overall gastrointestinal discomfort after short-term ingestion and 2) the effect on gastrointestinal symptoms of long-term consumption of IRSCE when administered at a dose compatible with its future commercial use.

Materials and methods

Subjects

Fifty-three healthy volunteers (34 men, 19 women) 18 to 67 y old, with an average weight of 67.3 kg and body mass index of 22.05 kg/m², were followed during the studies. All subjects gave written consent to the protocol, which was approved by the local ethical committee, and received compensation for their participation. Volunteers were healthy on physical examination; none had gastrointestinal symptoms or a history of gastrointestinal surgery, except for appendectomy. None of the participants was taking any treatment, except for contraceptives, or had received antibiotics for 2 mo before the studies. No other medication was allowed during the studies. All volunteers were asked to maintain a stable diet and none of the subjects consumed a special diet.

Study 1: Effect of short-term exposure to two doses of IRSCE on overall gastrointestinal discomfort

The effect of IRSCE was assessed in a double-blind, crossover study. Eighteen subjects during three consecutive 6-d periods, in a randomized order, consumed a morning instant coffee drink in which a sachet containing 10 g of sucrose alone (control period) or IRSCE at two doses was diluted. The composition of the coffee drinks is presented in Table 1. On the evening of day 5, subjects were asked to take a standardized meal and not to eat until they were given a standardized breakfast the next morning. The breakfast included four cereal bars and the coffee drink. Subjects were provided with printed sheets to record overall abdominal discomfort every 15 min for the first hour, half hourly for the subsequent 2 h, and then hourly for 6 h and asked to rank it with a visual analogic scale ranging from 0 cm (none) to 10 cm (very great discomfort). The analysis was done by using the measurement in centimeters from the origin of the scale to the mark made by the subject.

Study 2: Effect of long-term exposure to IRSCE at expected ingested dose on gastrointestinal symptoms

Thirty-five subjects were selected at the inclusion visit and were given diet guidelines to avoid food rich in fiber and others prebiotics contained in some dairies, sweets, and chewing gums. During a 14-d run-in period, subjects were asked to record their daily stool number and fill a questionnaire on their food consumption. This period was designed to verify the normality of food consumption. This period was designed to verify the normality of food consumption. The increase of the content of inulin in IRSCE raises the question of its gastrointestinal tolerance. Indeed, like other nondigestible carbohydrates, inulin consumption can be associated with an increase of flatulence, bloating, abdominal pain, and changes in stool consistency or frequency [18–20]. Until now, to our knowledge, no study has addressed the digestive tolerance of soluble roasted chicory extract with high inulin content and all the data published were obtained with inulin that had been purified. In this study we therefore aimed to assess in healthy subjects 1) the effect of two doses of IRSCE on overall gastrointestinal discomfort after short-term ingestion and 2) the effect on gastrointestinal symptoms of long-term consumption of IRSCE when administered at a dose compatible with its future commercial use.


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<table>
<thead>
<tr>
<th>Table 2 Composition of one tested drink, taken twice a day, during long-term consumption double-blind versus placebo study</th>
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<td>Composition</td>
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<tr>
<td>Sucrose (g)</td>
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<tr>
<td>IRSCE (g)</td>
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<tr>
<td>Inulin equivalent (g)¹</td>
</tr>
<tr>
<td>Soluble coffee (g)</td>
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<tr>
<td>Water (mL)</td>
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IRSCE, inulin-rich soluble chicory extract

* Sucrose and IRSCE were given in a single sachet. Sachets were identical in appearance and had to be dissolved in hot water.

¹ Inulin content in IRSCE was measured according to the Association of Official Analytical Chemists 99708 method (data not shown).

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<table>
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<tr>
<td>Sucrose (g)</td>
<td>4.1</td>
<td>0</td>
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<td>0</td>
<td>4.1</td>
</tr>
<tr>
<td>Inulin equivalent (g)¹</td>
<td>0</td>
<td>2.5</td>
</tr>
<tr>
<td>Soluble coffee (g)</td>
<td>6.8</td>
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<td>Water (mL)</td>
<td>250</td>
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Results

Study 1: Effect of short-term exposure to two doses of IRSCE on overall gastrointestinal discomfort

The analysis of the evolution of overall gastrointestinal discomfort according to the time of ingestion (Fig. 1) showed a slight but significant (P = 0.05) increase in overall

![Fig. 1. Short-term consumption double-blind crossover study design. Time changes of mean analogic scores in the three periods as reported on overall gastrointestinal discomfort questionnaires for 8 h (n = 18). IRSCE, inulin-rich soluble chicory extract.](image-url)
gastrointestinal discomfort during the 14-g IRSCE (i.e., 7.8 g inulin) period compared with the control period. In contrast, the 8.9-g IRSCE (i.e., 5.0 g inulin) period did not significantly differ from the control \( (P > 0.05) \) or the 14-g IRSCE \( (P > 0.05) \) periods.

**Study 2: Effect of long-term exposure to IRSCE at expected ingested dose on gastrointestinal symptoms**

Compliance was very high in both groups \((96.3 \pm 2.9\% \text{ for placebo and } 97.2 \pm 2.4\% \text{ for IRSCE})\) and no significant modification was evidenced in the food regimen. No significant changes in flatulence \( (P = 0.11) \), bloating \( (P = 0.94) \), abdominal pain \( (P = 0.49) \), stool consistency \( (P = 0.55) \), and frequency \( (P = 0.37) \) were observed between the placebo and 8.1-g/d IRSCE (i.e., inulin 5.0 g/d) groups (Fig. 2). In addition, no significant changes in individual symptoms were observed between the two groups when the beginning of the period (days 1–14) was compared with the remaining period (days 15–28; Fig. 3).

**Discussion**

By changing the industrial process to produce soluble roasted chicory extract, we have been able to obtain a natural inulin-rich extract, IRSCE, that contains around 60% of inulin and other potential bioactive compounds such as polyphenols. Preliminary in vitro analysis has shown that IRSCE has an antioxidant activity and prebiotic stimulating effect on *B. adolescentis* (Ripoll et al., in

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**Fig. 2.** Long-term consumption double-blind versus placebo study. Time changes of daily scores of gastrointestinal symptoms during the 8.1-g/d IRSCE (i.e., inulin 5.0 g/d) or placebo \( (n = 17) \) ingestion periods. Scores for flatulence \( (A) \), bloating \( (B) \), and abdominal pain \( (C) \): 0 = none; 1 = weak, 2 = moderate, 3 = high, 4 = very high. Scores for stool number per day \( (D) \) and stool consistency \( (E) \): 0 = liquid, 1 = soft, 2 = regular, 3 = hard, 4 = very hard. IRSCE, inulin-rich soluble chicory extract.
preparation). Moreover, several studies have suggested that the combination of dietary fibers such as inulin with other bioactive compounds like plant secondary metabolites or minerals can optimize the overall beneficial effect of each compound taken individually [21–23]. In particular, a recent study on rats has shown that a diet containing purified native inulin or dehydrated chicory exerts different effects on mineral metabolism and digestive fermentation, with a synergism between inulin and other nutrients found in chicory crude fractions [24]. Therefore, new food products based on IRSCE could have additional benefits in nutrition.

The increase of inulin content in soluble roasted chicory extract may also lead to an increase in unwanted symptoms such as gastrointestinal symptoms, as previously reported in several studies [8,18,19,25–28]. The present study is the first that has evaluated the digestive tolerance of a soluble roasted chicory extract naturally rich in inulin after a short- or long-term period of consumption.

A double-blind, crossover study in 18 subjects was performed to select the IRSCE dose that should be used in the commercial formulation. A drink containing sucrose or 5.0 or 7.8 g of inulin in IRSCE was ingested randomly every morning for a week and, when compared with controls, only a significant slight increase in overall abdominal discomfort was observed with the drink containing 7.8 g of inulin. Whatever the periods, overall gastrointestinal discomfort was scored from 3.5 to 6.0 cm on a 10-cm scale. This apparently high score in healthy subjects, even in the control period, is likely to be due to the special attention of volunteers to record symptoms or to the large volume of coffee ingested at once.

Based on the data of the first study and to have a study representative of consumer behavior, we selected the daily dose...
of 5.0 g of inulin, which can be achieved with a commercial formulation and a regular drinking pattern, e.g., two cups a day. This fits with the traditional behavior of instant-drink consumers in terms of quantity and frequency of serving. The product was tested in a double-blind versus placebo study in 35 healthy subjects during a 4-wk consumption period. The data indicated that the product was well tolerated with no difference compared with the placebo, even at the beginning (first 2 wk) of consumption. Under a diet excluding only food rich in fiber and other prebiotics, symptoms were felt in the two periods as absent or weak.

Some previous data on inulin tolerance have shown that at doses equal to or higher than 5 g/d, administrated at one time, an increase in abdominal symptoms can be observed [12,19,20,25,29–31]. With doses from 5 to 20 g/d, the subjects usually report a mild increase in flatulence and borborygmi [18,26,29–31]. With doses equal to or higher than 5 g/d, administrated at one time, an other prebiotics, symptoms were felt in the two periods as

Conclusion

Consumption of IRSCE, containing 5 g of inulin, is well tolerated by healthy subjects. This new food ingredient presenting naturally high inulin content in a chicory matrix combined with other potential bioactive compounds can be a suitable ingredient to develop food products rich in fiber and functional food applications.

Acknowledgments

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References