

SHORT COMMUNICATION

Effect of whole and ground Salba seeds (*Salvia Hispanica* L.) on postprandial glycemia in healthy volunteers: a randomized controlled, dose-response trialH Ho¹, AS Lee², E Jovanovski¹, AL Jenkins¹, R DeSouza^{1,3,4} and V Vuksan^{1,2,5}

OBJECTIVE: Incorporation of seeds into food products may attenuate postprandial glycemia. Whether these should be consumed as whole or in ground form is not known.

SUBJECTS/METHODS: Using an acute, randomized controlled crossover design, the glycemic response of 13 healthy participants (6M:7F; 25.4 ± 2.6 kg/m²) was studied on nine separate occasions. Test meals consisted of 7, 15 or 24 g of whole or ground Salba baked into white bread, and three control breads matched for energy, and macronutrient profile. Capillary blood samples were collected at fasting and over 2 h post consumption.

RESULTS: A significant effect of dose ($P=0.04$), but no effect of form ($P=0.74$) or dose-form interaction ($P=0.98$) was found. No adverse events were reported.

CONCLUSION: This study demonstrates that both ground and whole Salba are equally effective in attenuating blood glucose levels in a dose-dependent manner when incorporated into bread. Flexibility in the use of either the ground or whole seed may increase the ease of incorporation and acceptability as a dietary supplement.

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INTRODUCTION

Seeds can be rich sources of dietary fiber, omega-3 fatty acids, vegetable protein and micronutrients, factors which have been implicated to have various health benefits.^{1–3} Consequently, addition of seeds to bakery products has become a common practice. Presently, little research is available to address whether they should be consumed as whole or in ground form. Although there is general consensus that the nutrients from the ground seeds will be more bioavailable,^{4,5} grinding may adversely affect the food matrix. Once ground, the seeds are prone to oxidation and rancidity, which not only compromises their taste and odour, but limits shelf life.

The aim of the current study was to compare the physiological efficacy of Salba, a single variety of *Salvia Hispanica* L consumed whole or ground, on postprandial glycemia. Recently, we published in *The Journal* results of a study, demonstrating an acute hypoglycemic effect with increasing doses of ground Salba.⁶ To date, studies conducted by our group and other investigators^{1–3,6} have used finely ground Salba. However, the seed is commercially available in both whole and ground forms. Therefore, we wished to determine whether these two forms produce comparable effects on postprandial glycemia. To our knowledge, no such studies have been conducted.

SUBJECTS AND METHODS

A total of 13 healthy individuals (6M:7F; body mass index = 25.4 ± 2.6 kg/m²) were enrolled in the study. Exclusion criteria included consumption of any

prescribed medications or dietary supplements, which may alter glucose metabolism. The study was approved by the research ethics board of St Michael's Hospital. Written informed consent was obtained from all participants.

A randomized, controlled crossover design was used. Randomization was carried out using a Random Number Table and implemented by the Study Coordinator. All participants consumed all test meals and attended the clinic at St Michael's Hospital on nine mornings, separated by at least 48 h, following a 10–12 h fast. Finger-prick capillary blood was collected in the fasting state and at 15, 30, 45, 60, 90 and 120 min post meal, and analyzed using the glucose-oxidase method (YSI 2300 STAT Analyzer, Yellow Springs, OH, USA).

Experimental meals contained 50 g of available carbohydrate from white bread alone or with the addition of 7, 15 or 24 g (low, medium and high dose, respectively) of whole or ground Salba baked into the bread, prepared according to standard recipes using an All-In-One Pro Bread-maker (The Black & Decker Co, MD, USA). The three control breads were each matched for energy, protein and fat to the levels of Salba using egg whites and margarine (Supplementary Table 1). Salba is a brand name used to describe a white variety of seeds grown by Compañía Inversora Agropecuaria (Buenos Aires, Argentina) that is the result of selective breeding from the black *Salvia hispanica* L. (commonly known as Chia).

Statistical analysis

Incremental areas under the curve (iAUC) for blood glucose were calculated geometrically using the trapezoid rule.⁷ A two-way ANOVA was used to evaluate the main effects of form (whole versus ground), dose (low, medium and high) and their interaction. Statistical analysis was

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performed using NCSS-2000 (NCSS, Kaysville, UT, USA). Results were expressed as mean \pm s.e.m. and significance was set at $P < 0.05$.

In order to detect a change in the primary outcome, blood glucose iAUC of 25 ± 18 mmol \times min/L with 80% power at a level of $P < 0.05$ ($\alpha = 0.05$ and $1 - \beta = 0.8$), a total of 11 participants were required to participate in this study.

RESULTS

The iAUC for the three control breads that were matched for macronutrients (Supplementary Table 1S) to the low, medium and high dose Salba breads were 151.6 ± 19.8 , 124.8 ± 10.2 and 145.6 ± 15.9 mmol \times min/L, respectively. The iAUC of the ground Salba breads for the low, medium and high doses were 125.5 ± 14.6 , 116.9 ± 12.5 and 111.1 ± 8.8 mmol \times min/L, respectively, and similarly, for the whole Salba breads were 124.3 ± 15.5 , 111.9 ± 15.7 and 107.3 ± 10.7 mmol \times min/L, respectively (Supplementary figure 1S Supplementary Table 2S). As there were no statistical differences in the iAUC of the three control breads, the mean of the results (140.7 ± 9.1 mmol \times min/L) was used for the comparison with the Salba-containing breads. A significant main effect of dose ($P = 0.04$), but no effect of form ($P = 0.74$), and no dose–form interaction ($P = 0.98$) was found. This suggests that although low, medium and high doses of whole and ground combined forms reduced blood glucose iAUCs by 20, 28 and 35%, respectively, compared with the mean of the control breads, no difference in glucose response was found between whole and ground forms of Salba within the same dose level (Figure 1). No adverse events were reported.

DISCUSSION

In the present study, we aimed to investigate whether the two forms of Salba produce comparable effects on postprandial glycaemia. Similar to our previous study,⁶ we demonstrated that Salba reduces blood glucose iAUC in healthy participants in a dose-dependent manner. Furthermore, we present novel data indicating no differential effects of whole versus ground forms of Salba on lowering postprandial glycaemia in humans.

It has been postulated that Salba's hypoglycemic properties are mainly due to its content of highly viscous dietary fiber, which is found in the seeds' mucilage (a viscous substance produced by seeds when exposed to water or human digesta).³ Although there

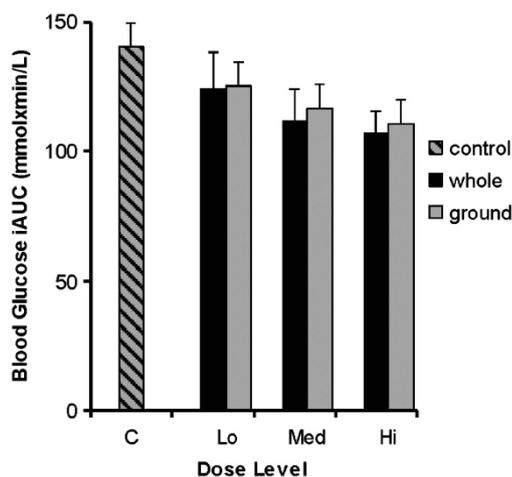


Figure 1. Mean incremental blood glucose AUC of 13 participants consuming white breads, containing either 7 g (low), 14 g (medium) or 24 g (high) doses of ground or whole Salba seeds. The control represents the mean response to the three energy and macronutrient-matched control breads. All meals contained 50 g of available carbohydrate. Values are means \pm s.e.m. i AUC, incremental area under the curve; C, control; Lo, low; Med, medium; Hi, high.

is a general consensus that nutrients from ground seeds should be more bioavailable, as seen with flax seed,⁵ our results indicate no difference in glucose response between whole and ground Salba. Early extraction experiments reveal that the flax seed coat consists of five distinct layers, with $\sim 58\%$ of the flax mucilage incorporated into the inner spermoderm layer (which is covered by the epiderm).⁸ In contrast, modern extraction and imaging studies describe *Salvia Hispanica* L mucilage as being localized to the outer three layers of the seed coat.⁹ This structural difference may make the fiber from the Salba accessible and easy to penetrate to the surrounding seed coat, irrespective of the seed form, and be the reason for the comparable hypoglycemic outcomes.

These results illustrate the versatility and practicality of Salba for consumption. In addition to baking finely ground Salba into white bread, which we previously studied, results from the current study indicate that baking whole Salba into white bread would yield similar blood glucose outcomes. Additionally, grinding and storing the seeds in the presence of oxygen may result in higher rates of oxidation and rancidation of omega-3 fatty acid. Therefore, baking whole, rather than ground, Salba into white bread may add an alternative option to extend its shelf life.

Limitations and future studies

Although other common seeds, such as flax seeds, have demonstrated comparable health outcomes¹⁰ in ground form and are compositionally similar to Salba, the same results would not necessarily translate to the whole form. Obvious structural and physical differences preclude application of present results to all other seeds, including flax. Future research is still required to elucidate whether the beneficial long-term effects of ground Salba can be replicated with whole Salba in both healthy and diabetic individuals. Further studies are also required to determine whether baking Salba onto other bakery products will yield similar blood glucose reductions.

CONFLICT OF INTEREST

V Vuksan: received grant support for an earlier study on Salba conducted in 2001–02 from Chia Nova Co (Toronto, Ontario, Canada); received honoraria for scientific advice and travel grants to present research at meetings from Salba Corporation (Buena Aires, Argentina), Salba Smart Natural Products LC (Denver, CO, USA), Source Salba Inc (Toronto, Ontario, Canada), Core Naturals Inc (Winter Spring, FL, USA) and Salba OLE Ltd. (Toronto, Ontario, Canada); holder of an American (No. 7326404 B2) and Canadian (No. 2410556) patent for use of viscous fiber blend in diabetes, metabolic syndrome and cholesterol lowering; received honoraria as a consultant for CANTOX Co. (Toronto, Ontario, Canada), InovoBiologic Inc. (Calgary, Alberta, Canada) the manufacturer of the viscous fiber blend PGX, a product based on Dr Vuksan's research; receives remuneration as VP and part owner of Glycemic Index Laboratories, Inc, a contract research organization. AL Jenkins: was a consultant for InovoBiologic, Inc. (Calgary, Alberta, Canada); receives remuneration as Director of Research and part owner of Glycemic Index Laboratories, Inc. The remaining authors declare no conflict of interest.

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Supplementary Information accompanies this paper on European Journal of Clinical Nutrition website (<http://www.nature.com/ejcn>)