Glycemic index of whole grain breads produced from different cereals: a randomized cross-over study in healthy volunteers

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Background

Bread is a staple food in Northern Europe and the most important carbohydrate source in Norway, according to the National Dietary survey Norkost-4 (Myhre 2024). Whole grain and fiber content, and processing are the main determinants for the glycemic index and the glycemic response to different breads (Ballance 2020, Schadow 2023, Goletzko 2016). The main cereal for bread production is wheat, which by far outnumbers the other grains suitable for bread production oat, rye and barley.

There is a lot of knowledge on determinants of the glycemic index when it comes to processing and ingredients, but little is known about differences between the different cereals, despite known deviations in amount of fiber and type of fiber. In particular, oat and barley contain the dietary fibre beta-glucan, which has been shown to affect postprandial metabolism (Revheim 2024). On the other hand, wheat and rye contain other dietary fibres such as arabinoxylans (Frolich 2013).

Dietary fibre (DF) content and composition of the main cereals used for bread production (Frolich 2013):

Component	Wheat	Rye	Oats	Barley
Total DF	13.5	19.9	10.2	15.2
Arabinoxylan	5.6	8.9	2.0	5.2
Cellulose	2.5	2.9	1.3	1.9
β-Glucan	0.8	1.5	5.0	4.6
Fructan	1.3	4.1	0.2	1.6
Klason lignin	0.8	1.1	1.4	0.7

The glycemic index of food stuffs is determined under standardized conditions and compared to the same amount of glucose as reference (Brouns 2005). In order to achieve a stable estimate for the comparison, the glucose testing should be conducted in the same person three times under standardized conditions, while the test food is consumed once. The amount of carbohydrates should be 50 g per test meal, and blood glucose values should be measured at baseline, and after 15, 30, 45, 60, 90 and 120 minutes.

A more diverse bread production from different grains would also be important for climate aspects and the degree of self-sufficiency, as cereals other than wheat can be successfully grown in Scandinavia.

We want to test 4 breads for the glycemic index, made of 100% either wheat, oat, barley or rye, and in addition compare the glycemic response of the different cereals to wheat. This will require that healthy test persons participate 7 times in the study (4 breads and 3x glucose). The study will provide valuable information on the postprandial effects of different cereals and will offer potential for dietary counselling and variation.

Main hypothesis

Bread prepared from different cereals (100% whole grain, developed and produced by Nofima, Ås) will cause a significantly different glycemic response compared to wheat bread in healthy volunteers.

Breads prepared from different cereals (developed and produced by Nofima, Ås) will differ in their glycemic index as tested under standard conditions in healthy volunteers.

Main objectives

To investigate whether the blood glucose response is different after ingestion of whole grain bread prepared from oat, barley or rye compared to bread prepared from wheat

To investigate the glycemic index of whole grain breads prepared from different cereals.

To investigate whether the insulin increase is different after ingestion of whole grain bread prepared from oat, barley, rye or wheat.

Work plan

Healthy volunteers will consume the different types of bread in a randomized, clinical cross over study. The study will be conducted at the Research Unit for Health Surveys (https://www.uib.no/en/ruhs), a core facility and collaborative project of the Medical Faculty at UiB and Helse Bergen, and will be part of a master thesis in clinical nutrition. Breads for testing will be produced at Nofima (responsible researcher: Simon Ballance).

Study Design

Healthy volunteers will be recruited by advertisements in social media and newspapers. They will be invited to a screening visit, which includes a clinical investigation, questionnaires on self-reported health and a non-fasting blood sample for measurement of glucose and HbA1c, mainly to exclude participants with undiagnosed diabetes mellitus.

Volunteers fulfilling the inclusion criteria will be invited to the main study. The order of testing the different breads and the glucose will be in random order for each volunteer, with a wash out period of at least 48 h between two tests. The volunteers will arrive at 8 am at the Research Unit, then a fasting blood sample is taken, and one of the bread is ingested in random order, within 10 minutes and in a blinded fashion (as this is an investigation with real food, difficulties in the blinding cannot be excluded, but will be minimized as far as possible). Further blood samples are taken at 15, 30, 45, 60, 90 and 120 minutes.

During the 24 h preceeding the test, it is required that the volunteers avoid strenuous physical activity and refrain from smoking or consuming alcohol the evening before a test. Each volunteer will receive counselling for a high carbohydrate standard meal the evening before each test and then remain fasting from 20.00 the night before a test. Water consumption is not restricted.

The study design follows the guidelines for glycemic index testing (Brouns 2005) which is the generally accepted method for glycemic testing.

Test products:

The breads will be produced at Nofima in a pilot scale bakery (registered with Mattilsynet for commercial food production). Each bread will be portioned at Nofima to have 50 g available carbohydrate and then shipped frozen to Bergen and thawed before the test day.

Outcomes:

The main outcome variable is the difference in the area under the curve of blood glucose after the breads prepared from oat, barley and rye compared to bread prepared from wheat.

Another main outcome is the glycemic index of the different breads, assessed by comparing the area under the curve of blood glucose to that of glucose.

Secondary outcomes include the increase in insulin, the satiety sensations during the postprandial period (measured by a visual analogue scale), and the blood concentrations of gastrointestinal hormones.

Inclusion and exclusion criteria

Eligible participants will be healthy adults who are willing to participate in the study and who are between 18 and 60 years old.

Exclusion criteria are pregnancy and breast-feeding, reduced ability to give informed consent, alcohol or other substance abuse, and use of drugs that may interfere with glucose concentrations. Chronic diseases like cardiovascular diseases, cancer, or chronic obstructive lung disease are a reason for exclusion when they occurred during the last three years and require continued treatment. Diabetes mellitus is a reason for exclusion.

Study procedures

Blood sample taking:
The participants will receive an intravenous catheter at each study day for sampling of venous blood.
Measuremet of glucose and insulin:
Glucose will we measured with Hemocue Glucose 201 system, a point-of-care device recommended for monitoring of blood glucose. The Hemocue Glucose 201 system is based on the modified glucose dehydrogenase principle with photometric measurement of glucose.
Venous blood will be centrifugated and serum will be stored in the Nutrition Intervention biobank for future analyses of insulin.

Power calculation

Calculation of sample size is based on the change in glucose concentrations. Previous studies (Rieder 2019) have shown that 12 subjects will provide 80% power to detect a difference in AUC120min (primary parameter) of 30% with alpha = 0.05. Assuming 20% of subjects drop-out at least 15 persons ought to be recruited into the study.

Safety and participants' issues

Breads are produced in a pilot bakery which is approved by the Food authority in Norway and only ingredients suitable for human consumption will be used. Therefore, consuming the breads is regarded as having very low risk.

Within this study, only blood sampling may involve some risk to the volunteers. All data will be stored and processed after de-identification at the SAFE server solution of UIB with only the project leader having access to the code. This will ensure that no conclusion can be drawn on individual patients. No individual patient data will be published or made available for persons who are not in charge of the study.

Time line
Spring 2025: application to the ethic committee
August 2025 – March 2026: inclusion of participants and conduction of the tests
March – June 2026: statistical evaluation and report writing (master thesis in clinical nutrition)
Autumn 2026: analyses of insulin in stored samples
January – June 2026: writing of the scientific publication

Plan for dissemination

The project is part of a master thesis in clinical nutrition at the University of Bergen and will be published as master thesis. Further, a scientific publication is planned also including insulin analyses. Dissemination to the interested public is planned by contribution in social media and via the communication office at UiB.

Role of participants

Principal investigator:

Prof. Jutta Dierkes (clinical nutrition): Writing of the study protocol, supervision of the trial, supervision of master students, writing of reports.

Research Unit for health surveys at UiB / HB (RUHS): practical conduction of trial

Master student: Conduction of the study, recruitment of volunteers

Nofima, Ås

Simon Ballance biochemist PhD, food technology senior researcher at Nofima, responsible for characterisation of flours and bread production and characterisation

Sileshi G.Wubshet biochemist PhD: Nofima: bread production, data analysis

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