

A Mini Review on Biomarkers of Whole Grain Barley and Whole Grain Wheat Intake*

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Abstract

1 Introduction

Whole grains (WGs) and their processed food could have health beneficial effects. However, epidemiologic studies showed mixed results due to subjective self-report based food exposure measurement[1]. Using Biomarkers of Food Intake (BFIs) can potentially measure food exposure in population more objectively with accuracy and details[2].

Alkylresorcinols (ARs) and their metabolites were widely reported and validated biomarkers for WGs intake. In plants commonly consumed for food, ARs only present high amounts in rye and wheat, especially concentrated in their bran parts[3]. Therefore, ARs have the possibility to be used as biomarkers for whole grain wheat and rye intake.

Increasing evidence showed that, different WG cereal types (such as wheat, rye, oat and barley etc.) could benefit health differently. However, classical self-reported measurement tools used in observational studies could cause biases and confoundings to distinguish each cereal type. Therefore, discovering BFIs of each whole grain type could potentially provide a tool to accurately quantify their exposures.

This mini-review aimed at systematically examining available literatures to obtain information of potential biomarkers for WG barley and wheat intake. This will prioritize further identification and validation of the thesis work.

2 Materials and Methods

This review referred the systematic BFIRev methodology[4]. The flowchart was included in Appendix (Fig-2)

*This is part of Tu Hu's master thesis work supervised by Lars Ove Dragsted and Gözde Gürdeniz

The objective of this literature review was to identify and evaluate reported potential biomarkers for dietary assessment for whole grain wheat and whole grain barley.

Keywords as suggested in the guidelines[4] were used to search in 3 database (PubMed, Web of Science, Scopus). Keywords used for searing BFI barley in human: (barley) AND (biomarker* OR marker* OR metabolite* OR biokinetics OR biotransformation OR pharmacokinetics) AND (intake OR meal OR diet OR ingestion OR consumption OR eating OR food) AND (human* OR men OR women OR patient* OR volunteer* OR participant*) AND (trial* or experiment OR study) AND (urine OR plasma OR blood OR serum OR excretion OR hair OR toenail OR faeces OR faecal water). The first element was changed to wheat for wheat intake biomarker searching.

Due to limited amount of searching results, barley searching scope was expanded to animal studies. Therefore, the keyword (animal* OR goat OR sheep OR cow OR mice OR mouse* OR animal model* OR dog*) was used to replace the previous 'human*' subjects. In addition, 'feed' was added to 'food' entry.

Other database including HMDB[5], FoodDB[6], PhenolExplorer[7], Dictionary of Food Compound[8] were also used to explore compounds present exclusively in WG barley and wheat.

In order to verify the uniqueness of compound, the same keywords combinations were used but with compound name instead of 'wheat' and 'barley'.

3 Results

3.1 WG barley

The literature search got 129 records after removing duplicate records from merged 3 database search results. However, within them, none of the studies directly investigated WG barley intake biomarkers. This could be explained by limited dietary exposure of barley in population. Although barley is the 4th most produced cereal grains worldwide. Most of them is used for brewing or feed. Approximately only 4% is directly consumed[9].

When the scope expanded to animal studies, the search results still did not show any direct research about BFIs. Most of studies were interested in how barley feed can benefit the growth of animal or quality improvement of animal-source products[10, 11].

A 2-month intervention study[12] incorporated 75% refined drum wheat and 25% WG barley. The fecal samples showed significant change in microbiota and metabolome after intervention[12]. However, no specific metabolite can indicate WG barley intake.

ARs and their metabolites may not indicate WG barley intake. Several observation studies[13, 14] investigated correlation between ARs metabolites and whole grain intake. Although these studies tried to cover more whole grain species, for example, one study[14] listed 7 types of regularly consumed WGs

in American populations in the Food Frequency Questionnaire (FFQ)¹, barley was not solely listed. Therefore, although ARs and their metabolites got good correlation with these 'Whole-grain intake'. Readers should be cautious to apply these markers to WG barley intake. In addition, ARs concentration in cereal barley is much lower compared with WG wheat and rye, with similar concentration with refined wheat and rye flours (Table-1).

| Cereal | Conc. range in cereal | Conc. average or range in WG flour | Conc. average in refined flour | Main homologues | C17:C21 homologues ratio |
|--------|-----------------------|------------------------------------|--------------------------------|-----------------|--------------------------|
| Rye | 360-3200 | 972 | 90 | C17, C19, C21 | 0.8-0.9 |
| Wheat | 761-8390 | 490-710 | 36 | C19, C21 | 0.07-0.1 |
| Barley | 55.8-98.2 | NA | NA | C19, C21, C25 | NA |

Table 1: Presence of ARs in Cereal Grains, adapted from [15–17](unit: $\mu\text{g/g dm}$), conc. varies due to different species and milling methods.

Most search results focused on barley’s *effect biomarkers* as defined by Dragsted[18] and Gao[19], such as bowel health indicators[20], postprandial glucose and insulin response[21], lipid profiles and cardiovascular diseases (CVD) markers[22], etc. However, in these intervention studies, compliance monitoring lacked objective markers.

Further search results in food chemistry, cereal science and plant science showed some compounds exclusively present in barley. These could give hints for further identification. The results were summarized in Table-2.

| No | Candidate biomarker | Formula | Chemical group | Presence in Food | Reference |
|----|------------------------|--|-----------------------------------|---|-----------------|
| 1 | Hordenine | $\text{C}_{10}\text{H}_{15}\text{NO}$ | alkaloid | germinating barley, beer and other plants | [23] |
| 4 | Hordatine A | $\text{C}_{28}\text{H}_{38}\text{N}_8\text{O}_5$ | alkaloid | only reported in barley | FoodDB (002330) |
| 4 | Hordatine B | $\text{C}_{29}\text{H}_{40}\text{N}_8\text{O}_5$ | alkaloid | only reported in barley | FoodDB (002328) |
| 2 | Distichonic acid A | $\text{C}_{10}\text{H}_{18}\text{N}_2\text{O}_8$ | gamma amino acids and derivatives | only reported in barley | FoodDB (18164) |
| 3 | Distichonic acid B | $\text{C}_{10}\text{H}_{18}\text{N}_2\text{O}_8$ | gamma amino acids and derivatives | only reported in barley | FoodDB (018165) |
| 5 | 14,16-Nona cosanedione | $\text{C}_{29}\text{H}_{56}\text{O}_2$ | ketone | only reported in barley | FoodDB (013891) |
| 6 | N-Norgramine | $\text{C}_{10}\text{H}_{12}\text{N}_2$ | indole | only reported in barley | FoodDB (017815) |

Table 2: Candidate Biomarkers for WG barley intake

To conclude, barley, especially WG barley attracted a lot of interest due to its health beneficial effects for chronic disease. However, due to barley’s limited exposure in the population, currently there’s no reported biomarkers can indicate its intake. However, a lot of sparse information was reported from

¹Dark breads, High-fiber or bran cereals, Cooked cereals and grits, Regular granola, Granola bars and cereal bars, Plain popcorn (no butter) or low-fat microwave popcorn, Buttered or gular microwave popcorn

cereal and food chemistry could give hints to identification and validations of WG barley’s intake biomarkers.

3.2 WG wheat

The literature search got 312 results after removing duplicate records from merged results. XXX were used.

ARs (Figure1) and their metabolites (3,5-DHPPTA, 3,5-DHPPA, 3,5-DHBA and 3,5-DHBA glycine) were widely reported, validated and applied biomarkers for WG wheat and rye intake. Total ARs were used as biomarkers for overall WGs wheat and rye exposure. In order to distinguish WG wheat and rye. The ratio of C17:0/C21:0 was used. ARs, depending on different milling methods and grain species, varies the concentration and homologues compositions (Table-1). The homologues ratio C17:0/C21:0 was firstly proposed in cereal science to distinguish WG rye and wheat[24]. The ratio was further proposed as a marker to indicate which cereal dominates in the diet: if the ratio is close to 1.0, rye dominated; close to 0.1, wheat dominates[25, 26].

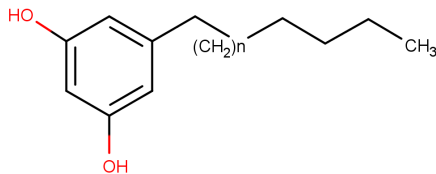


Figure 1: Structure of ARs

| Dietary factor | No. subjects | Study design | Sample type | Analytical method | Candidate biomarker(s) | Reference |
|---|--------------|--|-------------|-------------------|----------------------------|-----------|
| WG wheat WG rye | 39 | intervention, cross-over, randomized | plasma | GC-MS | ratio of AR C17:0/C21:0 | [25] |
| Healthy new nordic diet ² | 166 | intervention, parallel, randomized, multi-center (18/24 weeks) | plasma | GC-MS | ratio of AR C17:0/C21:0 | [27] |
| WGs ³ | 266 | randomized, parallel-group, intervention | plasma | GC-MS | Total ARs | [28] |

Table 3: Biomarkers of Wheat Intake Reported in Intervention study

²containing more rye than control group

³This study was conducted in UK. WG wheat is the main WG source in British population. Considering this, although several types of WGs were used (WG wheat, corn, oats, barley and rice), WG wheat made up around 65% of the intervention

In this study[28], total ARs were reported as WG wheat intake biomarkers. This intervention was conducted in UK. In British population, the major whole grain source is wheat. Rye was rarely consumed. Therefore, plasma ARs got a good correlation with whole grain (WG) wheat intake.

| Type of WG | No. subjects | Sample type | Analytical method | Candidate biomarker(s) | Associated with | Reference |
|------------------|--------------|--------------------------------|-------------------|-------------------------------|-----------------|-----------|
| WGs ⁴ | 104 | spot urine | GC-MS | ARs metabolites (DHBA, DHPPA) | FFQ | [29] |
| WGs ⁵ | 2845 | fasting and non-fasting plasma | GC-MS | AR C17:0/C21:0 | FFQ | [30] |

Table 4: Biomarkers of Wheat Intake Reported in Observation study

[30] This study investigated

Searching results also showed some *Food compound intake biomarkers (FCIBs)* research as defined by Gao[19] such as phenolic compounds[31], benzoxazinoids[32] and phytoestrogen[33]. These compounds also present in other food, not specific for WG wheat. These results were summarized in Appendix.

Their concentrations varied in different cereal grains. Therefore, a combination of their metabolites could potentially indicate intake of different cereals.

4 Conclusions

Currently, there’s no biomarkers reported for WG barley intake both in human and animal studies.

Total ARs and their metabolites were reported to potentially indicate WG wheat and rye intake. The homologues ratio of ARs C17:0/C21:0 was proposed to distinguish which whole grain type dominates in the diet.

Several phytochemicals could potential become candidate markers of WG wheat and barley intake. However, they need to be further validated.

5 Discussions

In order to clarify each sub-type of cereal’s health beneficial effects, it is important to accurately quantify exposure amount of each sub-type. BFIs showed their strengths and potentials in studying WGs.

it is essential to discover intake biomarker for each sub-type cereal grain. Currently, most studies showed interest in WG effect biomarkers.

As discussed in [1], one of the challenges in BFIs discovery of WG is that the chemical compositions of most of WGs were not systematically due to limited systematic research on phytochemicals

⁴This study was conducted in US. WG wheat is the dominant WG source in US populations.

⁵This cohort studies investigated WGs conc. in different EU countries’ population.

6 Appendix

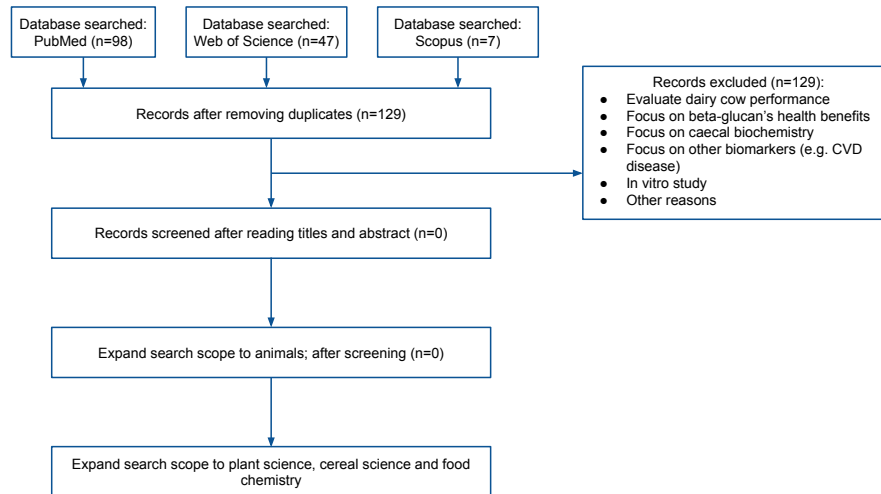


Figure 2: Flow chart of literature searching and screening for articles of barley intake biomarkers

| Dietary factor | No. subjects | Study design | Sample type | Analytical method | Candidate biomarker(s) |
|---|--------------|--|-------------|--|--|
| Wheat bran, Wheat aleurone | 14+13 | randomized, cross-over, intervention | plasma | LC-MS/MS (Microbiology assay for folate) | betaine choline folate dimethylglycine (DMG) |
| None-bread, White bread, WG bread | 155 | observation ⁶ | urine | HPLC-qTOF-MS | Benzoxazinoid-related metabolites (HHPAA, HBOA glycoside) ARs-related metabolites(DHPPA glucuronide, DHPPTA sulphate), microbial |

Table 5: Reported markers distinguishing WG wheat intake, but NOT specific

⁶ dietary exposure measured from FFQ

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