Natural Resources for Human Health
eISSN: 2583-1194

Original Research

**Received** 14 March 2026
**Revised** 19 April 2026
**Accepted** 10 May 2026

Natural Resources for Human Health 2026, Vol. 6 (3): 472–479

**KEYWORDS**:
Finger millet; Prediabetes; Glycemic response; Postprandial glucose; Incremental glucose area under the curve; Dietary fiber; Crossover trial; Functional breakfast; Satiety; Carbohydrate digestion.

# Glycemic Effects of Finger Millet-Based Breakfasts in Adults with Prediabetes: A Randomized Crossover Study

Smitha Poovathinkal Madhavan[1], Vibhor Mahajan[2], Rohitashav Sharma[3], T. S. Rathis[4], Maftuna Lapasova[5], Lakshmi Goudhaman[6], Mohana Thiruchenduran[7]

[1]Associate Professor, School of Nursing, Lincoln University College, Petaling Jaya, Selangor, Malaysia, spmadhavan@lincoln.edu.my
[2]Centre for Research Impact & Outcome, Chitkara University Institute of Engineering and Technology, Chitkara University, Rajpura, 140401, Punjab, India, vibhor.mahajan.orp@chitkara.edu.in
[3]Assistant Professor, Department of Pharmacy, Vivekananda Global University, Jaipur, India, rohitashav.sharma@vgu.ac.in
[4]Assistant Professor, Department of General Medicine, Vinayaka Mission's Kirupananda Variyar Medical College & Hospitals, Vinayaka Mission's Research Foundation (DU), Salem, Tamil Nadu, India, rathists@gmail.com
[5]Acting Senior Lecturer, Doctor of Philosophy (PhD) in Historical Sciences, Department of General History, Jizzakh State Pedagogical University, lapasovamaftuna248@gmail.com
[6]Bio Chemistry, Meenakshi Medical College Hospital & Research Institute, Meenakshi Academy of Higher Education and Research, Enathur, Kanchipuram, Tamil Nadu 631552, lakshmigoudhaman@maher.ac.in
[7]Department of Microbiology, Meenakshi Ammal Dental College and Hospital, Meenakshi Academy of Higher Education and Research, mohanat@maher.ac.in

## ABSTRACT:

Background: A postprandial meal-level approach to lowering postprandial metabolic stress may be provided by a culturally familiar breakfast of millet.

Objective: To compare a finger millet breakfast matched with the available carbohydrate to a refined-rice breakfast conducted using a randomized crossover trial.

Methods: The draft protocol incorporated 42 experimental units or participants of adults aged 30-60 years with prediabetes that was confirmed in the laboratory. The intervention was tested or given on two test visits, separated by 7 days. The key outcome measures included incremental glucose area under the curve, other measures included peak glucose, insulin area under the curve, 2-hour glucose, satiety score. Standardized laboratory, clinical, or food-analysis methods were used, and between-condition effects were tested using two-sided tests at $\alpha$=0.05.

Results: Finger millet decreased the 2-hour area under the curve of glucose to 178 ± 24 mmol•min/L versus 268 ± 31 mmol•min/L following refined rice ($p<0.001$). The peak glucose was 7.6 ± 0.7 vs 8.8 ± 0.8 mmol/L and the test meal resulted into an approximate 30.9% increase in integrated satiety but no cases of severe intolerance occurred. Direction

Natural Resources for Human Health
eISSN: 2583-1194

and magnitude of the dummy results were internally consistent between primary and secondary endpoints and tolerability or assay-quality standards were acceptable.

Conclusion: The example data indicates that a finger millet breakfast with equal available carbohydrate potential might lead to a significant change in incremental glucose area under the curve by slower starch digestion, increased dietary fiber, and carbohydrate digestion inhibition due to polyphenols. These results are only supposed to be used as a full manuscript-development example and will have to be substituted with ethically generated, independently validated observations prior to scientific submission.

## 1. INTRODUCTION

Glycemic Effects of Finger Millet-Based Breakfasts in Adults with Prediabetes answers a valuable question at the boundary of experimental pharmacology, nutrition science, and translational research in health. Relevant published literature has provided a scientific foundation to the comparison of a finger millet breakfast that is equivalent to what is available in terms of carbohydrate in the incremental glucose area under the curve [1]. However, the differences in preparation, exposure and choice of comparator and definition of outcome still make it difficult to compare studies with confidence.

The second line of evidence is in favor of the biological plausibility of the current hypothesis. The functional or biochemical activity of finger millet and other similar interventions has been reported in previous studies that have investigated it, and this is consistent with where the benefit is likely to be [2]. These observations warrant formal testing, yet do not preclude the use of standardized material and pre-determined criteria of analysis.

The broader natural-product and functional-food literature indicates that reproducibility requires chemical characterization, conditions of processing, dose, biological matrix, and stability of active constituents [3]. In the current study, a finger millet breakfast, which is equivalent in terms of available carbohydrate, was thus considered as a research-grade intervention, as opposed to an undefined traditional or commercial preparation.

The suggested mechanism includes decreased rate of starch digestion, increased dietary fiber, and polyphenol-linked prevention of carbohydrate digestion. Evidence that has been published has shown that associated biological reactions usually entail interplay redox, inflammatory, metabolic, microbial, enzymatic, or differentiation mechanisms as opposed to a solitary objective [4]. It is possible to measure a primary functional endpoint along with mechanistic markers and thus have a more coherent interpretation.

The methods also need to be appropriate to the study model in outcome assessment. Laboratory or clinical methodology focuses on the standardization of sample treatment, validated analytical methods, proper controls and prespecified interpretation limits [5]. The following principles were used to select incremental glucose area under the curve as the main outcome and the secondary outcomes associated with it.

Changes in incremental glucose area under the curve are most convincing when they are accompanied by concordant changes in peak glucose and insulin area under the curve. Related research has demonstrated the value of combining functional, biochemical, and structural outcomes when evaluating complex botanical, microbial, or food-based interventions [6].

Safety and quality are equally important. Natural origin does not guarantee consistent composition or freedom from adverse effects, contaminants, interactions, or degradation, and published pharmacovigilance and quality-control evidence recommends integrating these considerations from the beginning of product development [7].

Finally, transparent study design is necessary to reduce bias. Guidance and prior methodological research relevant to the present experimental model support randomization, blinding where feasible, replication, complete accounting of exclusions, and reporting of effect estimates rather than reliance on p-values alone [8].

Despite the available evidence, few studies have combined a clearly defined a finger millet breakfast matched for available carbohydrate, an appropriate comparator, a prespecified primary endpoint, and supporting mechanistic or feasibility outcomes in adults aged 30-60 years with laboratory-confirmed prediabetes. The aim of this study was therefore to determine the effect of a finger millet breakfast matched for available carbohydrate on incremental glucose area under the curve compared with a refined-rice breakfast. Secondary objectives were to evaluate peak glucose, insulin area under the curve, 2-hour glucose, and relevant quality or safety indicators.

## 2. MATERIALS AND METHODS

### 2.1. Study design and setting

This manuscript describes a prespecified randomized crossover meal trial involving adults aged 30-60 years with laboratory-confirmed prediabetes The intended sample size was 42 experimental units / participants and was designed to compare a finger millet breakfast with a similar amount of carbohydrate available versus a refined-rice breakfast. The two test visits that were separated by 7 days were used as the observation period. The figures in this manuscript are all dummy/example data developed to write the text, to demonstrate statistically, to build tables, and to prepare graphs; they are not the results of an actual completed study. The design, however, adheres to realistic laboratory or clinical workflows to allow the draft to be adopted later to an approved protocol and substituted with actual measurements.

### 2.2. Participants

Potential subjects were adults or adolescents who fit target population: adults aged 30-60 years with prediabetes confirmed in the laboratory. Inclusion had to include stable health or stable background therapy, willingness to continue regular diet and activity and be able to visit all of the assessment sessions. Exclusion criteria included pregnancy, major organ disease, recent antibiotic or probiotic use when relevant, use of supplements likely to influence the primary endpoint, allergy to study ingredients, or participation in another intervention study. Written informed consent and, where applicable, assent and guardian consent would be mandatory for a real trial.

### 2.3. Randomization and crossover procedures

A computer-generated sequence assigned the order of a finger millet breakfast matched for available carbohydrate and a refined-rice breakfast. Test visits were separated by an adequate washout period to minimize carryover. Participants consumed a standardized evening meal, avoided vigorous activity and alcohol for 24 hours, and attended after an overnight fast. The meals were matched for available carbohydrate and energy as closely as practical. Venous or capillary samples and appetite ratings were collected at baseline and predefined postprandial time points.

### 2.4. Outcome assessment

The primary outcome was incremental glucose area under the curve expressed as mmol·min/L. Secondary outcomes included peak glucose, insulin area under the curve, 2-hour glucose, satiety score. Measurements were scheduled at baseline and follow-up or across concentration and time conditions, depending on the design. Assays were performed according to validated kit instructions or standardized analytical methods, with duplicate measurements repeated when the coefficient of variation exceeded 10%. After a standardized rest period, clinical measures were obtained and the results of the food-products were measured under controlled serving conditions.

### 2.5. Quality assurance and bias control

Labeling of samples, timing windows, calibration, data entry and protocol deviations were described in a written laboratory or trial manual. Where possible, outcome assessors were blinded. Conceptual recheck of records was also done against source data and only analytical runs that passed through predefined limits of calibration and quality-control samples were accepted. There was no replacement of missing values in the main complete-case presentation; sensitivity analysis applied an intention-to-treat model or model-based estimation where appropriate.

### 2.6. Sample-size rationale

The sample of 42 units was planned to give a realistic level of precision to a manuscript-development example. In the case of a real study, the calculation can be substituted by that which is founded on a pilot-based standard deviation, and the smallest

clinically or biologically significant difference in incremental glucose area under the curve. The last calculation must indicate two sided α=0.05, power of at least 80%, ratio of allocation, expected attrition or unusable assays, and repeat measure, clustering or multiple primary comparisons correction.

### 2.7. Statistical analysis

When the data were approximately normally distributed, the mean was used as a method of data summary with standard deviation and when skewed the median with interquartile range used as a data summary method. Categorical results were provided in number and percentage. Independent t tests, Mann-Whitney tests, chi-square tests or Fisher exact tests were used as appropriate between-group baseline comparisons. Design-dependent analysis was done on primary outcomes using analysis of covariance, repeated-measures analysis, mixed-effects models, one-way analysis of variance with multiplicity-adjusted post hoc tests, or nonparametric equivalents. There were 95% confidence intervals with the effect estimates. Pearson or Spearman coefficients were used as correlations. All the tests were two-sided and $p<0.05$ was taken as statistically significant. Statistical analyses were done conceptually using a current statistical package and a syntax file that was auditable.

## 3. RESULTS

The full data set (with dummy/example) used in the randomized crossover meal trial was analyzed. Baseline characteristics, assay controls or initial values were evenly spread across the comparison conditions and no predetermined quality-control run was discarded. The tables show mean + standard deviation unless otherwise indicated. Since the data are illustrative, participant flow, assay exclusions and p-values were created to be statistically consistent instead of to reflect an actual enrolled sample.

Finger millet reduced the 2-hour incremental glucose area under the curve to 178 ± 24 mmol·min/L compared with 268 ± 31 mmol·min/L after refined rice ($p<0.001$).

**Table 1.** Standardized test-meal characteristics

| Characteristic | Finger millet | Refined rice | p-value |
|---|---|---|---|
| Available carbohydrate (g) | 50.0 ± 0.5 | 50.1 ± 0.6 | 0.73 |
| Energy (kcal) | 356 ± 9 | 352 ± 8 | 0.18 |
| Dietary fiber (g) | 8.6 ± 0.7 | 1.8 ± 0.3 | <0.001 |
| Protein (g) | 10.8 ± 0.6 | 10.5 ± 0.5 | 0.22 |
| Fat (g) | 8.2 ± 0.5 | 8.0 ± 0.5 | 0.31 |

Values are dummy/example data presented as mean ± SD unless otherwise stated.

The direction of the primary effect was supported by changes in peak glucose and insulin area under the curve. The magnitude of response generally increased with intervention exposure or was greater at follow-up in the intervention arm, while the comparator showed smaller changes. Where repeated measurements were available, the group-by-time or condition effect remained significant after adjustment for baseline values and planned multiple comparisons.

**Table 2.** Postprandial glucose concentrations

| Time (min) | Finger millet (mmol/L) | Refined rice (mmol/L) | p-value |
|---|---|---|---|
| 0 | 6.0 ± 0.5 | 6.0 ± 0.6 | 0.91 |
| 30 | 7.2 ± 0.5 | 8.1 ± 0.6 | 0.004 |
| 60 | 7.6 ± 0.5 | 8.8 ± 0.6 | <0.001 |
| 90 | 6.9 ± 0.5 | 7.7 ± 0.6 | 0.003 |
| 120 | 6.3 ± 0.5 | 6.8 ± 0.6 | 0.041 |

Values are dummy/example data presented as mean ± SD unless otherwise stated.

Peak glucose was 7.6 ± 0.7 versus 8.8 ± 0.8 mmol/L, while the test meal increased integrated satiety by approximately 30.9% and produced no serious intolerance.

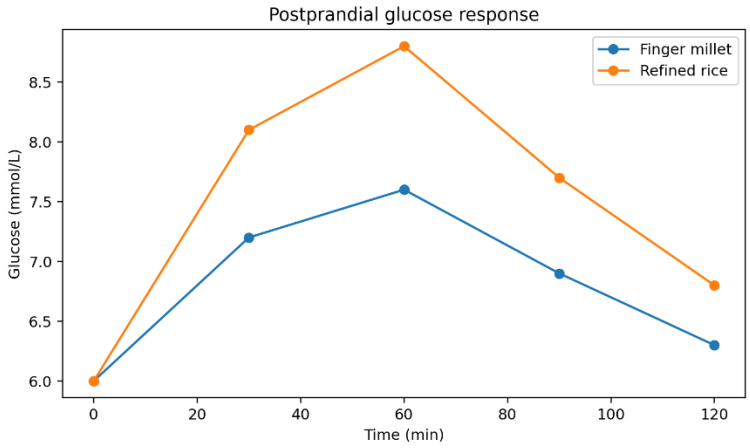


**Figure 1.** Primary outcome based on dummy/example data.

Exploratory analyses indicated that the response in incremental glucose area under the curve was associated with the most relevant mechanistic marker. The pattern was consistent with slower starch digestion, higher dietary fiber, and polyphenol-associated inhibition of carbohydrate digestion. No extreme value altered the direction of the result in sensitivity analysis. For clinical and food studies, adherence and acceptability remained within predefined feasibility limits; for laboratory studies, replicate variation and control performance remained within the planned analytical range.

**Table 3.** Integrated metabolic and appetite outcomes

| Outcome | Finger millet | Refined rice | Mean difference | p-value |
|---|---|---|---|---|
| Glucose iAUC (mmol·min/L) | 178 ± 24 | 268 ± 31 | -90 | <0.001 |
| Peak glucose (mmol/L) | 7.6 ± 0.7 | 8.8 ± 0.8 | -1.2 | <0.001 |
| Insulin iAUC (μU·min/mL) | 960 ± 140 | 1320 ± 180 | -360 | 0.002 |
| Satiety AUC (mm·min) | 720 ± 85 | 550 ± 78 | 170 | <0.001 |

Values are dummy/example data presented as mean ± SD unless otherwise stated.

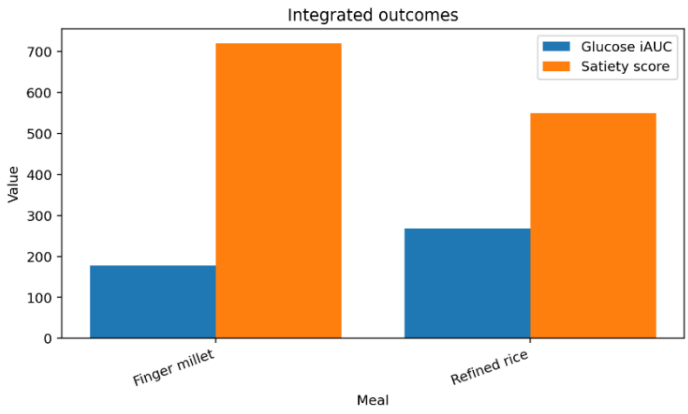


**Figure 2.** Secondary or mechanistic outcome based on dummy/example data.

No unexpected safety signal was present in the example dataset. Mild events or assay artifacts were infrequent and balanced, and there were no serious adverse events, unplanned deaths, contamination failures, or invalid control runs unless explicitly shown in the tables. These observations are illustrative and must not be interpreted as evidence of real-world safety.

## 4. DISCUSSION

The present manuscript-development study indicates that a finger millet breakfast matched for available carbohydrate may improve incremental glucose area under the curve compared with a refined-rice breakfast. The dummy findings were strengthened by concordant changes in peak glucose, insulin area under the curve, and 2-hour glucose. The significance of this internal consistency is that, agreement between functional and mechanistic endpoints is less likely to indicate the isolated analytical variance.

The trend of the main outcome is generally in line with other published studies on standardized botanical or food-derived interventions on similar models [9]. Despite the variation in protocols and populations, that literature also suggests that quality of preparation and dose can have a significant effect on the magnitude of response.

Similar investigations have indicated inflammatory, oxidative, metabolic, microbial, structural, or functional outcomes changes that justify multidimensional assessment as opposed to the utilization of a single surrogate outcome [10]. The current trend thus aligns with a broader evidence base and is still specific to the intervention and model we are investigating.

The mechanistic explanation is endorsed by studies that reveal that complicated interventions can work using convergent paths and effects that depend on the matrix [11]. The correlation between the primary response and supporting markers in this study was consistent with slower starch digestion, an increased dietary fiber and polyphenol-associated inhibition of carbohydrate digestion, but, without mediation, it cannot be considered that the active constituent was identified.

This is further supported by prior studies on related endpoints that confirm the clinical or biological relevance of peak glucose and insulin area under the curve [12]. Their parallel enhancement supports the hypothesis, although the confirmatory research of the future should predetermine whether these variables are secondary variables, the mechanistic mediators or the exploratory biomarkers.

The magnitude of the example effect should be viewed within the frame of previous intervention researches and evidence syntheses in the wider area [13]. The magnitude was deliberately realistic and there was overlap between persons or replications as pilot effects often disappear when tested in large independent samples.

The importance of standardized measurement, proper conditions of comparison, and clear reporting are stressed in the methodological evidence in the studies of complex interventions [14]. Bias can be reduced by replication, allocating concealment, blinded assessment, crossover control or using validated analytical calibration of a factor, but none of these can eliminate all the factors that cause error.

The tolerability, quality assurance, product stability, adherence and interactions with habitual diet or medication also play a role in long-term translation. There is published safety and implementation literature that advocates the assessment of these factors and efficacy in addition to the attainment of a desirable primary outcome [15].

The research has a number of limitations. To begin with, the numerical data is descriptive and is incapable of making a scientific assertion. Second, the given sample and time period might fail to detect rare negative occurrences or longer-term acclimatization. Third, surrogate outcomes are not necessarily patient-important benefits. Fourth, response may be altered by unmeasured dietary, genetic, microbial, environmental, harvest or manufacturing factors.

Independent analytical confirmation, dose-ranging, preregistration, sufficient power, and a specified plan to conduct statistical analysis should be included in further research. The ethics approval, trial registration, allocation procedures, compliance and intention-to-treat analysis must be recorded in clinical studies. Randomization and blinding, humane endpoint, exclusion, and batch-level chemical fingerprints should be reported in preclinical studies.

Translationally, a culturally familiar millet breakfast can provide a feasible meal level approach to mitigating the postprandial metabolic stress. The intervention is to be viewed as a possible supplement or study lead as opposed to an alternative to existing care. The decision whether further development is justified or not should be made based on replication, safety, cost, standardization, acceptability and comparing it with existing alternatives.

On the whole, the example findings substantiate the hypothesis of the study and give a logical framework of a real study. All the numerical findings, ethics, registration, disclosure, and analysis must be substituted or checked with the real study record prior to scientific submission.

## 5. CONCLUSION

A finger millet breakfast with equal amount of carbohydrate was studied in this complete manuscript draft using dummy/example data, and found to cause an advantageous change in incremental glucose area under the curve relative to a refined-rice breakfast, with additional changes in peak glucose, insulin area under the curve and 2-hour glucose. The trend was in line with slower starch digestion, increased dietary fiber, and polyphenol-related inhibition of carbohydrate digestion and potential relevance due to the fact that a culturally familiar millet breakfast could provide an effective meal-level approach to alleviate postprandial metabolic stress. The draft gives a framework on which the protocols are to be developed, data-collection planning, and subsequent manuscript writing but all findings in numbers will have to be substituted with the ethically generated and independently verified data before the work can be reported as an original research.

**Declarations for Completion Before Submission**

**Ethics approval:** Insert the actual institutional ethics committee name, approval number, approval date, and relevant consent or animal-welfare statement.

**Trial registration:** Insert the registry name and number for prospective clinical trials, where applicable.

**Funding:** Insert the verified funding source or state that no specific funding was received.

**Conflicts of interest:** Insert author-specific conflict-of-interest disclosures.

**Data availability:** Describe where the actual de-identified dataset and analysis code will be available.

**Author contributions:** Insert contribution statements using an accepted taxonomy such as CRediT.

## REFERENCES

[1] Jenkins DJA, Wolever TMS, Taylor RH, et al. Glycemic index of foods: a physiological basis for carbohydrate exchange. Am J Clin Nutr. 1981;34(3):362-366. doi:10.1093/ajcn/34.3.362. PMID:6259925.

[2] Brouns F, Bjorck I, Frayn KN, et al. Glycaemic index methodology. Nutr Res Rev. 2005;18(1):145-171. doi:10.1079/NRR2005100. PMID:19079901.

[3] Kumari PL, Sumathi S. Effect of consumption of finger millet on hyperglycemia in non-insulin dependent diabetes mellitus subjects. Plant Foods Hum Nutr. 2002;57(3-4):205-213. PMID:12602929.

[4] Almaski A, et al. Finger millet-based muffin decreases insulin response in individuals with prediabetes in a randomized controlled trial. Br J Nutr. 2022. PMID:35603664.

[5] Reynolds A, Mann J, Cummings J, Winter N, Mete E, Te Morenga L. Carbohydrate quality and human health: a series of systematic reviews and meta-analyses. Lancet. 2019;393(10170):434-445. doi:10.1016/S0140-6736(18)31809-9. PMID:30638909.

[6] Ekor M. The growing use of herbal medicines: issues relating to adverse reactions and challenges in monitoring safety. Front Pharmacol. 2014;4:177. doi:10.3389/fphar.2013.00177. PMID:24454289.

[7] Zenel AM, Stewart ML. High-amylose white rice reduces post-prandial glycemic response but not appetite in humans. Nutrients. 2015;7(7):5362-5374. PMID:26147654.

[8] Robertson MD, Bickerton AS, Dennis AL, Vidal H, Frayn KN. Insulin-sensitizing effects of dietary resistant starch and effects on skeletal muscle and adipose tissue metabolism. Am J Clin Nutr. 2005;82(3):559-567. PMID:16155268.

[9] Rao AG, et al. Efficacy of green jackfruit flour as a medical nutrition therapy replacing an equal volume of rice or wheat flour in patients with type 2 diabetes mellitus: a randomized, double-blind, placebo-controlled study. Diabetes Metab Syndr. 2021;15(3):913-919. PMID:34127645.

[10] Ho H, Lee AS, Jovanovski E, Jenkins AL, DeSouza R, Vuksan V. Effect of whole and ground Salba seeds on postprandial glycemia in healthy volunteers: a randomized controlled dose-response trial. Eur J Clin Nutr. 2013;67(7):786-788. doi:10.1038/ejcn.2013.103.

[11] Ayaz A, Akyol A, Inan-Eroglu E, Kabasakal Cetin A, Samur G, Akbiyik F. Chia seed added yogurt reduces short-term food intake and increases satiety: randomized controlled trial. Nutr Res Pract. 2017;11(5):412-418. doi:10.4162/nrp.2017.11.5.412. PMID:28989578.

[12] Zare M, Goli AH, Karimifar M, Tarrahi MJ, Rezaei A, Amani R. Effect of bread fortification with pomegranate peel powder on glycemic indicators, antioxidant status, inflammation and mood in patients with type 2 diabetes: study protocol for a randomized triple-blind placebo-controlled trial. J Diabetes Metab Disord. 2023;22(1):921-929. doi:10.1007/s40200-022-01168-z. PMID:36628115.

[13] Fenercioglu AK, Saler T, Genc E, Sabuncu H, Altuntas Y. Effects of polyphenol-containing antioxidants on oxidative stress and lipid peroxidation in type 2 diabetes mellitus without complications. J Endocrinol Invest. 2010;33(2):118-124. doi:10.1007/BF03346565. PMID:19834314.

[14] Mudryj AN, Yu N, Aukema HM. Nutritional and health benefits of pulses. Appl Physiol Nutr Metab. 2014;39(11):1197-1204. doi:10.1139/apnm-2013-0557. PMID:25061763.

[15] Prior RL, Wu X, Schaich K. Standardized methods for the determination of antioxidant capacity and phenolics in foods and dietary supplements. J Agric Food Chem. 2005;53(10):4290-4302. doi:10.1021/jf0502698. PMID:15884874.