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Pulse Crop Fortification Perspectives

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Greenhouse gas emissions, land use, and water use required for production of plant-based vs. animal protein sources 1, 2

Protein Source	Beef (20% protein)	Pork (20% protein)	Poultry (20% protein)	Eggs (13% protein)	Pulses (20-36% protein)
GHG (CO_2eqs / kg protein)	45 - 640	20 - 55	10 - 30	15 - 42	4 - 10
Land use (m2/yr/kg of protein)	37 - 2100	40 - 75	23 - 40	29 - 52	10 - 43
Water use liter/ g protein	112	57	34	29	19

[1] Mekonnen, M.M. & Hoekstra, A.Y. A Global Assessment of the Water Footprint of Farm Animal Products. *Ecosystems* 15, 401–415 (2012), [2] Nijdam, D., Rood, T. & Westhoek, H. The price of protein: Review of land use and carbon footprints from life cycle assessments of animal food products and their substitutes. *Food Policy* 37, 760–770 (2012)

Acknowledgements

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Lentil (*Lens culinaris* Medik.) – a source of iron

- ❑ Fifth most important pulse crop *(FAOSTAT)*
- ❑ Ingredient in plant-based diets
- ❑ Quick cooking
- ❑ Low-cost high-quality protein, vitamins, dietary fibre, and minerals

BUT……

- ➢ Phytic acid, tannic acid, and polyphenols
- ➢ Plant-based Fe is non-heme
- ➢ Lower bioavailability

Short history of lentil biofortication and fortification research……

2010-12 - First serious look at micronutrient profiles of lentil in Canada

- Biofortification was (still is) in the news
- Results: High levels of Fe, Zn, and also Se (abundant in soil) published in ***agronomy/plant science journals***

2013-15 – Bioavailability of Fe in lentil (like most cereal grains and pulses) shown to be mostly unavailable – ***nutrition journals***

2014-20 – Focus on increasing Fe and Zn through fortification of lentils

- Results are/will be published **in nutrition journals…**

Food as medicine: Selenium enriched lentils offer relief against chronic arsenic poisoning in Bangladesh. *Environmental Research 2019.*

***Judit Smits**, *Regina Krohn, #Evana Akhtar, Albert Vandenberg, #Rubhana Raqib

*Faculty of Veterinary Medicine, University of Calgary
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Note: Saskatchewan lentils have naturally high content of selenium

Conclusions from the 6-month Se trial

Our study showed first evidence that a high-selenium lentil diet compared to a low-Se diet:

- Reduced body burden of As
- Increased As excretion through urine
- No increased As lost through stool supporting that liver/bile excretion is not important in humans
- Improved health measures in an As-exposed population

- Long-term, larger scale, study needed to confirm results

Iron-fortified lentils:

A food-based, sustainable solution to reduce iron deficiency among adolescent girls in BANGLADESH

Yunus Fakir, Diane M. DellaValle (PhD, RDN, LDN) et al.

King's College, Marywood University,

University of Saskatchewan

ClinicalTrials.gov Identifier: NCT03516734

Iron-fortified lentils: Take-home messages

- **Anemia (27%), ID (9.6%) and IDA (6.7%) is prevalent** in Bangladeshi teen girls.

- **Average serum ferritin levels significantly increased** by 21.9% in the ***iron-fortified*** lentil group (**AND WAS MAINTAINED!**), compared to the other groups, after adjusting for inflammation, *upazila (district)* and age.

- Compared to the girls in the other groups at the end of the trial, **girls who consumed the iron-fortified lentils had:**

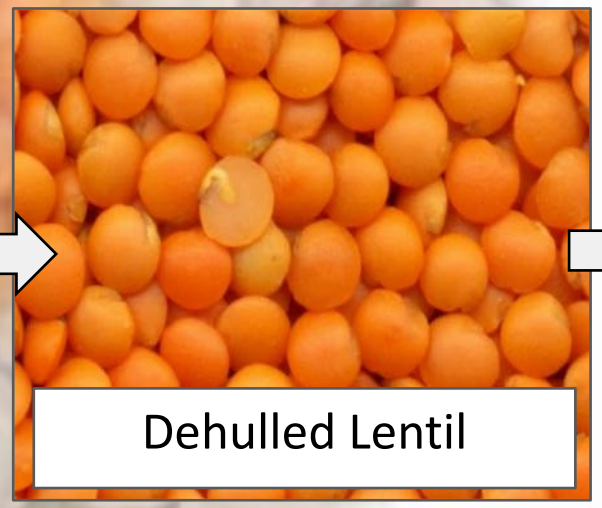
- **~60 lower chance** of developing clinical and sub-clinical iron deficiency anemia (<15, 15-30 µg/L)
- **51% lower chance** of developing clinical iron deficiency anemia (IDA) (sFer <15 ng/ml + Hb <12 g/dL)
- **70% lower chance** of developing sub-clinical IDA (sFer 15-30 ng/ml + Hb <12 g/dL)

Note: Fortification method was micronutrient solution applied to milled lentil dal

NOTE - 1 Publication is available now
- 3 Additional papers forthcoming from this study in the next 8-12 months.

Adding value to lentil using fortification technology – dual fortification to address Fe and Zn deficiency

Lentil – a potential candidate for Dual-fortification



Study 1: Dual-fortified milled lentil products - a sustainable approach to combat iron and zinc deficiencies in humans

Estimated average requirements based on FAO/WHO recommended iron and zinc intakes at 5% bioavailability

	1-3 years	4-6 years	19-50 years, Female	10-50 years, male
Iron (mg)	11.6	12.6	58.8	21.6
Zinc (mg)	6.9	8.0	8.2	11.7

Reference: WHO, 2006

Intrinsic Fe and Zn in Unfortified lentil

- Fe: ~ **6.5 mg /100 g** of lentil
- Zn: ~ **4.3 mg /100 g** of lentil

Lentil fortified with **16 mg of Fe & 8 mg of Zn /100 g of lentil**

Fe: ~ **21 mg /100 g of lentil**

Zn: ~ **14 mg /100 g of lentil**

nutrients MDPI

Article

Iron Fortification of Lentil (*Lens culinaris* Medik.) to Address Iron Deficiency

Rajib Podder [1], Bunyamin Tar'an [1], Robert T. Tyler [2], Carol J. Henry [3], Diane M. DellaValle [4] and Albert Vandenberg [1,*]

Current Developments in Nutrition CDN

This manuscript was submitted on November 04, 2020 in the journal "Current Developments in Nutrition" and is now in editorial review.

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Study 2. Sensory acceptability of dual-fortified milled red and yellow lentil (*Lens culinaris* Medik.) dal in Bangladesh

- Sensory properties differed significantly among all uncooked lentil samples but was not significant for cooked samples, with a few minor exceptions.
- Fortification process *minimally affected* the dual-fortified lentil compared to unfortified lentil samples for appearance, taste, odor, texture and overall acceptability

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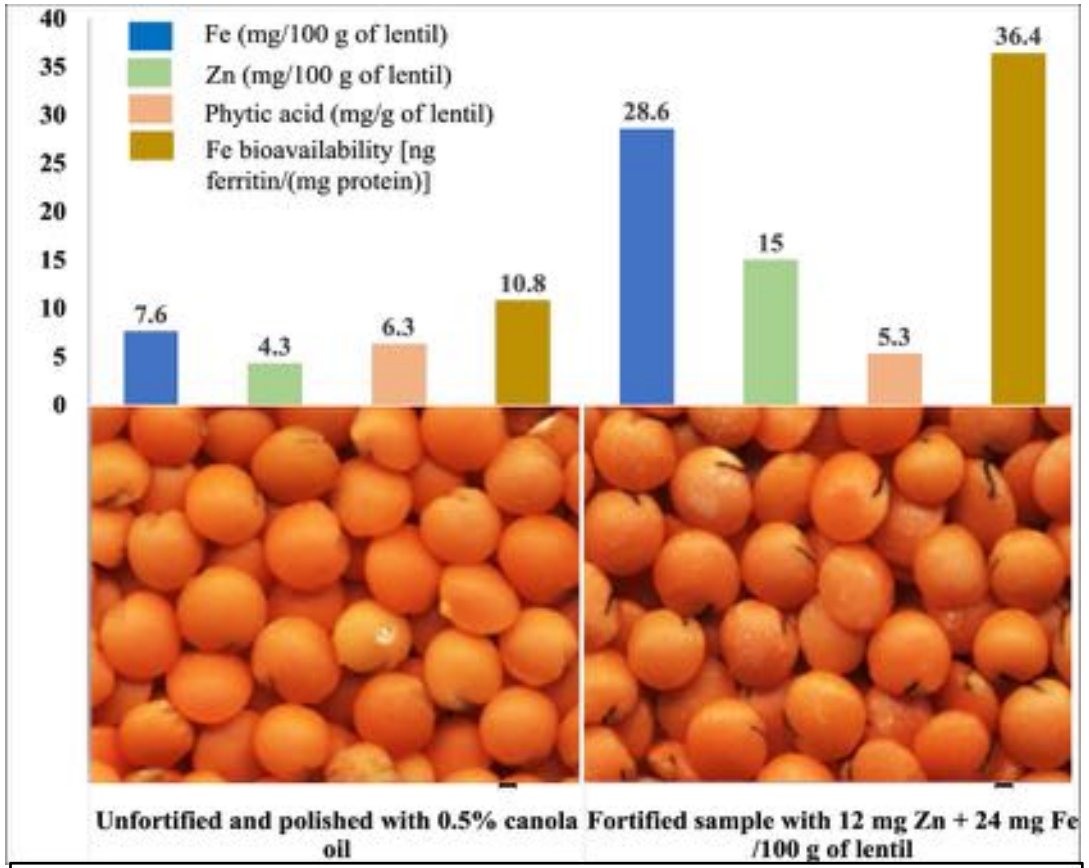
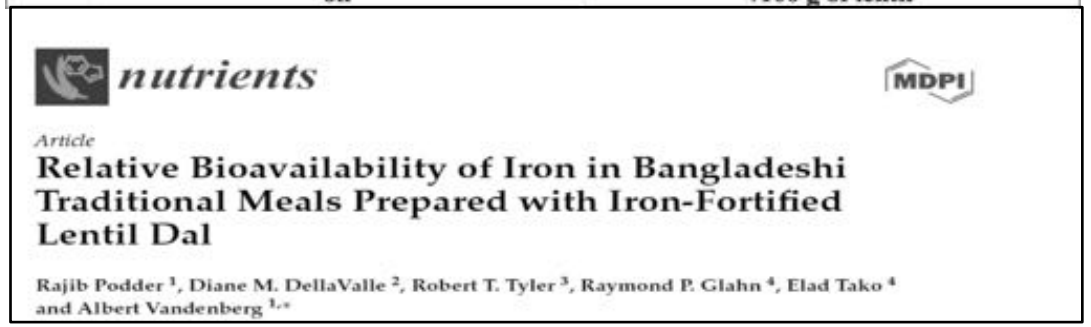
Study 3: Iron and zinc fortified lentil (*Lens culinaris* Medik.) demonstrates enhanced and stable iron bioavailability after storage




nutrients
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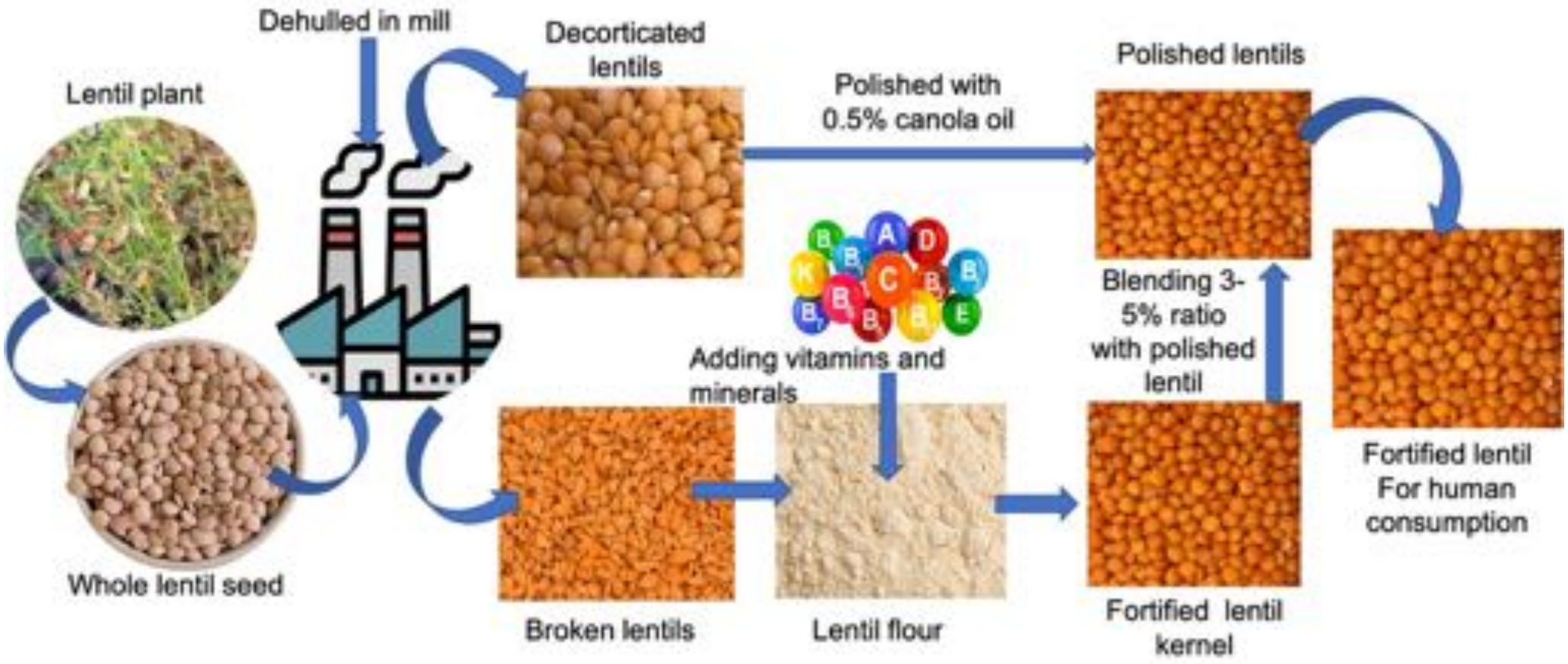
Article
Relative Bioavailability of Iron in Bangladeshi Traditional Meals Prepared with Iron-Fortified Lentil Dal
Rajib Podder [1], Diane M. DellaValle [2], Robert T. Tyler [3], Raymond P. Glahn [4], Elad Tako [4] and Albert Vandenberg [1,*]

- Fe, Zn and RFeB% increased significantly in all dual-fortified samples - but decreased 5-15% after one year of storage.
- PA concentration decreased by 8-15% after fortification in samples from two batches.
- RFeB% increased from 91.3 to 519.5% in Dual-fortified lentil sample fortified with 24 mg Fe and 12 mg Zn 100^{-1}g lentil compared to control.
- Significant Pearson correlations ($p \leq 0.01$) were observed between Fe vs. PA:Fe (-) molar ratio (MR), Fe vs. RFeB% (+), RFeB% vs. PA:Fe MR (-), and Zn vs. PA:Zn MR (-).

A manuscript from this study was accepted for publication in the Journal "Frontiers in Nutrition" on November 24, 2020.
Front. Nutr. | doi: 10.3389/fnut.2020.614812

Next Steps Proposed: Hot Extrusion Technology (HET) for Lentil – Fortification with Minerals ***and*** Vitamins



Fortified extruded lentil kernels

- Premix with broken lentil flour as carrier; shaped as a dehulled lentil kernel,
- Requires further processing of blending into rice before human consumption
- Fortified lentil kernels (extruded) contain highly concentrated vitamins and mineral levels.

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