Novel approaches to improve nutrient bioavailability in food aid products

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Food Matrix

- The nutrient & non-nutrient components of foods and their molecular relationships (chemical bonds) to each other

- Major food components
  - Carbohydrates
  - Protein
  - Fat

- Other Food Components
  - Micronutrients (vitamins & minerals)
  - Phytonutrients (polyphenols, carotenoids, flavanoids etc.)
  - Anti-oxidants
  - Anti nutritional factors
  - Probiotics

Bioavailability

- The proportion of a nutrient that is absorbed from the diet and used for normal body functions[1,2]

- Major bioavailability pathways[3]

  Nutrient release from the physicochemical dietary matrix
  Effects of digestive enzymes in the intestine
  Binding and uptake by the intestinal mucosa
  Transfer across the gut wall
  Systemic distribution & storage
  Metabolic and functional use

- The bioavailability of macronutrients is usually very high, more than 90% of the amount ingested[4]

1. Aggett PJ (2010). Population reference intakes and micronutrient bioavailability: a European perspective. American Journal of Clinical Nutrition 91(suppl):1433S-1437S.
2.. Hurrell R & Egli I (2010). Iron bioavailability and dietary reference values. American Journal of Clinical Nutrition 91(5):1461S-1467S. doi: 10.3945/ajcn.2010.28674F
3. http://www.eufic.org/en/food-today/article/nutrient-bioavailability-getting-the-most-out-of-food
4.Nutraceutical and Functional Food Components: Effects of Innovative Processing Techniques. *Edited by: Charis Michael Galanakis (2017)* ISBN: 978-0-12-805257-0

Goals of exploring food matrices

- Incorporate advances in food science & technology that have been excluded from food aid formulas
- Understand the 'real' effect that consuming food aid products has on recipients
- Create better food products that can carry energy and nutrition more effectively
- Design more 'cost-effective' products: optimized ingredients can lend higher nutritional value at similar costs

Food matrices in food aid

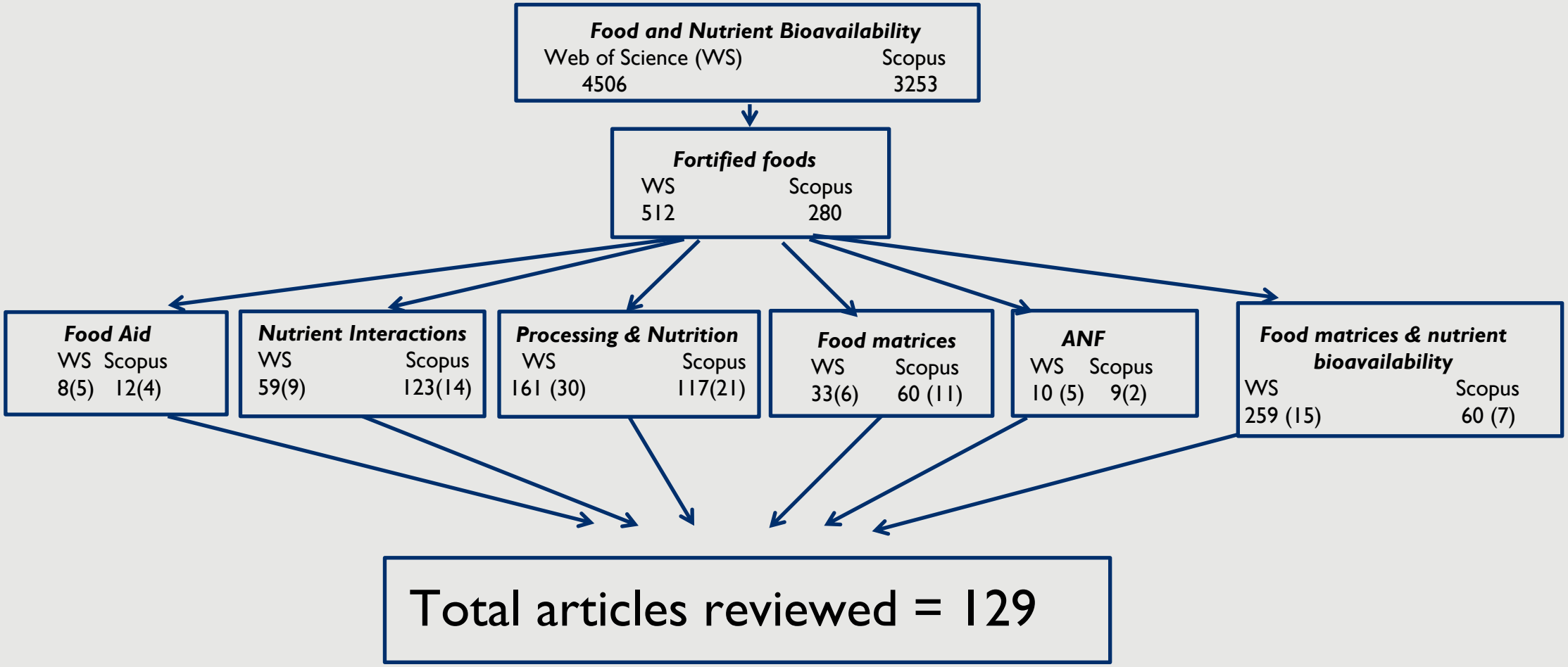
- Unprocessed

Wheat, corn, soybeans, lentils, milled rice, dry peas

- Processed

Fortified vegetable oil, textured soy protein, iodized salt, corn soy blend (roasted, extruded), RUTF (roasted, ground), high energy biscuits (baked)

Literature Review Search Strategy (2000-2018)



Bold & Italicized words are the keywords used for literature search
Numbers in parentheses are the actual articles that are relevant to this review; ANF – Anti-nutritional factors

High-potential areas for improvement

- Enhance energy density of porridges
- Improve protein quality and digestibility
- Improve shelf-life of food aid products
- Lower ω6:ω3 ratio in oils selected for food aid
- Reduce phytate content of food aid ingredients
- Reduce/eliminate mycotoxin contamination
- Address gut health issues of beneficiaries of food aid

Suggestions to improve bioavailability of food aid products

Recommendation	Potential Uptake	Category	Potential Uses	Comments
Diastatic Malt (0.25%)	Certain	Food additive	FBFs	Improve energy density of FBFs Improve protein digestibility Reduce phytates
Defatted wheat germ (15-20%)	Likely	Macronutrient	FBFs, plant based RUTF and RUSF, HEB	Source of high quality protein with branched chain amino acids higher than corn
Compaction of FBFs	Exploratory	Processing	FBFs	Improve shelf life
Canola Oil or blend of vegetable oils	Likely	Macronutrient	FBFS, RUTFs, HEB	Provide ω6:ω3 ratio as close to 1 Neurocognitive and immune development
Synthetic amino acids	Likely	Food additive	FBFs, plant based RUTF and RUSF, HEB	Provide highly bioavailble form of lacking/limiting amino acids
Yeast cell wall (0.1-0.25%)	Likely	Food additive	FBFs, plant based RUTF and RUSF, HEB	Mycotoxin binding
Oligosaccharides for gut health at 1.8%-6% of dry matter	Probably	Food additive	FBFs, plant based RUTF and RUSF, HEB	Need more information on use of fibers for undernourished population.

Diastatic Malt to Enhance Energy Density

Need

- Energy density of FBF porridge is 0.4-0.7kcal/g
- Protein digestibility can be improved
- Phytates in cereals and legumes reduce mineral bioavailability

Proposed Solution

✓Add diastatic malt (malted barley flour with Diastatic Power of 160-200°Lintner)

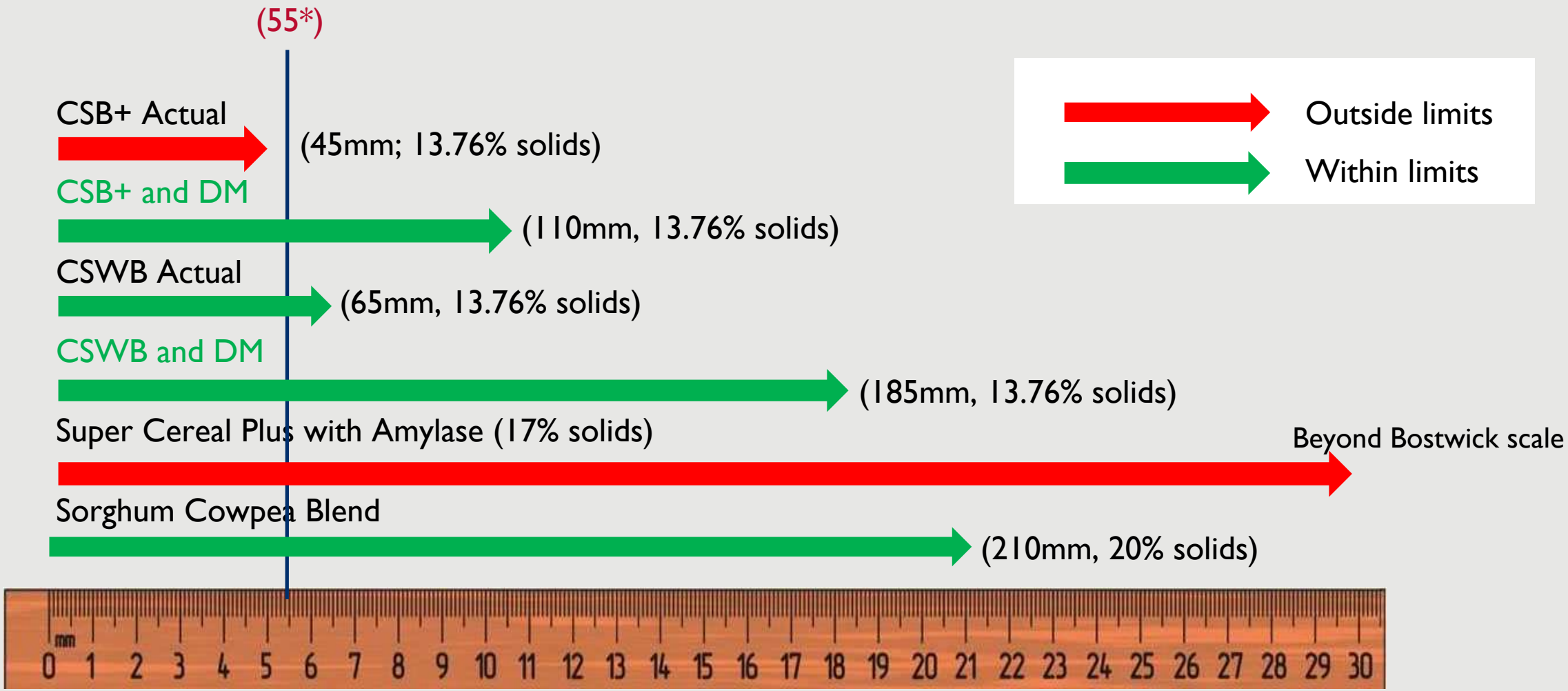
Role in Food Aid products

- Increase energy density of FBFs without increase in volume
- Improve protein digestibility
- Reduce phytates from plant based ingredients

Cost of malt flour: ~US$ 0.85/lb; **Addition Rate:** 0.25%

In 1 MT, 5.5 lbs of DM is needed x 0.85 = **$4.68 additional cost/ton**

FBFs – Bostwick values after 30s @ 45°C



*(55) USDA standards for CSB+; CSB+ = Corn Soy Blend Plus
FBFs = Fortified Blended Foods; DM = Diastatic Malt; CSWB = Corn Soy Whey Blend.

Malting based studies

Study	Study Group	Products	Outcome
Energy and nutrient intake increased by 47–67% when amylase was added to fortified blended foods—a study among 12- to 35- month-old Burkinabe children (Kampstra et al., 2016)	Children between 12-35 months, Burkina Faso	SC+ and SC (CSB, WSB, and RSB) with and without amylase CSB = extruded and drum dried	Addition of amylase significantly increased energy intake and consequently nutrient intake per serving; by 67% for SC+ (1.16 kcal/g) porridges in children aged 12–23 months and 47% for SC (1.03 kcal/g) porridges in children aged 24–35 months.
Does the consumption of amylase-containing gruels impact on the energy intake and growth of Congolese infants? (Moursi et al., 2003)	Infants between 18-24 weeks, Congo	Maize/soy flour with and without amylase	Consumption of amylase treated gruels allows an increase in energy intake from these gruels without affecting breast milk consumption
Effects of dietary viscosity and energy density on total daily energy consumption by young Peruvian children(Bennett et al., 1999)	Children between 8-17 months, Peru	Wheat flour, pea flour, full fat milk powder, and oil with and without amylase rich flour	Amylase liquefaction of High Density-High Viscosity porridges resulted in increased energy consumption by young children.
Power Flour (High Diastatic Milled Barley Malt) Its Important and Critical Role in the Care of Weanling Infants and the Severely Malnourished (Herlache, J.L., 2007)	----------	Malted Barley Flour	Milled high diastatic barley malt is a natural, inexpensive, food grade flour that contains naturally generated digestive enzymes. – Amylase, Protease, and Phytase
Development of weaning food formulations based on malting and roller drying of sorghum and cowpea (Malleshi et al., 1989)	----------	Malted sorghum and malted cowpea in the ratio of 70:30 and pearled sorghum and roasted cowpea in the same ratio	The malted food had lower cooked paste viscosity, and higher protein content and protein efficiency ratio as compared to unmalted counterpart.

Wheat Germ to Improve Protein Content

Need

➢Improve the protein quality of food aid products

Proposed Solution

✓Addition of toasted wheat germ

Role in Food Aid products

- Improve the protein quality

Cost: ~ US$ 0.52/lb; **Addition rate: ~** up to 20%

Special consideration: Wheat Germ potentially reduces shelf-life; needs to be assessed by accelerated storage studies

Toasted wheat germ cost-effectiveness

	Corn	TWG	Full fat soy	Protein (g/100g)	Energy (kcal/100g)	Cost/ton (USD)	Cost savings
CSB+	79%	----	20%	13	380	$1,140	0%
CSB+ & 5% TWG*	75%	4%	20%	14	380	$1,150	-1%
CSB+ & 10% TWG	71%	8%	17%	14	370	$1,090	5%
CSB+ & 15% TWG	67%	12%	15%	14	350	$1,020	10%
CSB+ & 20% TWG	63%	16%	12%	14	340	$960	16%

*Figures are based on the macro-ingredients, vitamin and mineral premixes amount to 1-5%, Costs are for indicative purposes:
Degermed yellow corn-0.55/kg, Full fat Soy-US$ 3.53/kg; TWG: $ 1.14/kg
CSB+- Corn Soy Blend Plus; TWG- Toasted wheat germ

Toasted Wheat germ based studies

Study	Product	Outcome
To study classification of defatted wheat germ proteins by amino acid composition, predicted nutritional quality, molecular weight distribution of subunits, and thermal properties (Zhu et al., 2016a)	Defatted wheat germ flour	Defatted Wheat germ has a well-balanced amino acid profile, which can make it a good vegetable protein supplement for cereal-based diets
Some Nutritional and Functional Properties of Defatted Wheat Germ Protein (Yiqiang et al., 2000)	Defatted wheat germ	Defatted wheat germ is abundantly nutritious, with high contents and equilibrium pattern of amino acids.
Nutritional assessment of cookies supplemented with defatted wheat germ (Arshad et al., 2007)	Defatted wheat germ enriched wheat flour cookies	The cookies containing 15% DFWG, were best regarding protein bioavailability in rats.
Defatted Wheat germ extract analyzed for antioxidant activity (Mahmoud et al. 2015)	Whole wheat germ and defatted wheat germ	Defatted wheat germ extract has anti-oxidant properties and oxidative stability. is a potential source of antibacterial agents that act mainly on Gram-positive and Gram-negative bacteria.
To estimate and compare apparent and standardized ileal digestibility of amino acid and nitrogen in wheat germs as non-traditional feed fed to growing pigs (Brestensky et al., 2013)	Wheat germ (only source of nitrogen) based experimental diet	The digestibility of amino acids and nitrogen of wheat germs is comparable with soybean meal which is the main protein source in diets for pigs. Therefore, it is possible to recommend the use of wheat germs as an alternative protein source,

Compaction to Extend Shelf Life

Need

➢Improve shelf life of FBFs by reducing moisture and oxygen migration inside packaging

➢Reduction in insect infestations

Proposed Solution

✓Compaction of FBFs

Role in Food Aid products

- Improved shelf life of FBFs
- Reduced shipping volumes

Compaction – Proof of Concept

Equipment

- Manually operated hydraulic press

Compaction Pressure

- 160 Bar (2320 psi)

Volume reduction due to compaction

- 70%

Friability

- Can be disintegrated with some force

Compaction based studies

Study (Authors, year)	Publication	Product	Outcome
Mechanical compaction of flour: The effect of storage temperature on dough rheological properties (Cenkowski et al., 2000)	Canadian Agricultural Engineering	Wheat flour with low extraction (75%) and high extraction (83%)	Compaction offers advantages for long term storage. It would reduce storage volume, slow down diffusion of oxygen into the flour during storage and, therefore, reduce oxidative processes and improve storage stability. Also, compacted flour would have more resistance to possible infestation by mites or other micro-organisms.
Sorption Isotherms of flour and flow behaviour of dough as influenced by flour compaction (Ramanathan & Cenkowski, 1995)	Canadian Agricultural Engineering	All purpose flour	The compaction of flour to 60% of its original volume can lead to a significant decrease in the storage volume and transportation cost.
Theory of granulation (Augsburger and Vuppala, 1997)	Handbook of Pharmaceutical Granulation Technology		The suitable way to compact dry powders is through pressure agglomeration which would not require other liquids or binders and subsequent drying. This process has less operating costs and requires simpler equipment
Size reduction and size enlargement (Snow et al., 1999)	Perry's Chemical Engineering Handbook		The overall effect of geometry of the confined space, nature of applied force, physical properties of the particulate material and of the confining walls control the ability of the material to form and maintain inter-particle bond during compaction
Caloric densification of rations (Barrett and Cardello)	Military Food Engineering and Ration Technology	First Strike Ration (FSR) vs. Meals Ready to Eat (MRE)	The FSR, on a daily or meal basis, represents a 50% reduction in volume when compared to MRE.

Novel Food Matrices Approaches

Technologies

1. Diastatic malt to improve energy density
2. Wheat germ to improve protein quality
3. Compaction to extend shelf-life

Benefits

✓ Improved nutrient bioavailability

✓ No major changes in the existing production set-up

✓ "Cost-effective"

Challenges

- Regulatory hurdles with some of the recommendations
- Industry cooperation with formula/processing changes?
- Funding to research/implement the recommendations
- For compaction: Additional manufacturing steps & costs of capital equipment

Thank You