Project number: 6753
Funding source: Department of Agriculture, Food and The Marine
Date: October, 2019
Project dates: March 2015-Sep. 2019

Development of Fortified Blended Foods using fermented buttermilk/cereal

Key external stakeholders:

Dairy Ingredient manufacturers, cereal providers, food formulators.

Practical implications for stakeholders:

- Development of process for the manufacture of fortified blended food powders (FBF) from reconstituted dairy powders and cereals
- New insights into the factors affecting the nutritional composition of FBF and their consistency/rheological behaviour on reconstitution and cooking.

Main results:

- Fortified blended food (FBF) was developed using an alternative process to that currently used by the World Food Programme for Super Cereal plus (WFP, 2015). The developed process involved wet blending fermented milk and parboiled cereal, co-fermentation of the blend, shelf drying the blend to a 'cake', milling to a base powder, and fortification of the base powder with vitamins, minerals and essential free fatty acids.
- Key factors found to affect the nutritional composition of the FBF and the consistency/viscosity characteristics of the reconstituted FBF were fermented milk-to-cereal ratio (1.5:1-4:1), cereal type (wheat, oats or barley) and co-fermentation time (0 – 72 h).
- Storage conditions (0- 18 months at 15, 30 or 37 °C) significantly impacted the functionality of the FBF powder. FBF stored at 15 °C was overall very stable for up to 18 months. Conversely, storage at 37 °C, and to a lesser extent at 30 °C, led to notable deterioration in the composition (concentrations of lactose and lysine), colour, and reconstitution behavior (water holding capacity, viscosity and flow) at storage times of ≤ 4 months.

Opportunity / Benefit:

The project findings provide new know-how and insight into the

- The design of innovative sustainable food products (e.g., fermented milk-cereal composites) with the additive nutritive, techno-functional, and flavour properties of different food groups.
- These products present a new export opportunity for Irish-based dairy ingredients and cereals.

Collaborating Institutions:

Teagasc Food Research Centre Moorepark, Fermoy, Co. Cork
School of Food and Nutritional Sciences, University College Cork

Contact Tim Guinee Email: tim.guinee@teagasc.ie

Teagasc project team: Prof. Tim Guinee, Ms. Ashwini Shevade

External collaborators: Prof. Nora O'Brien (project coordinator), Dr. Tom O'Connor, Dr. Yvonne O'Callaghan (University College Cork)

1. Project background:

Fortified blended food (FBF) is a category of 'specialized nutritious food' supplied by the World Food Programme to reduce the risk of malnutrition in food-insecure regions (WFP, 2015). FBF comprises two powder products, namely Super Cereal (SC), which is intended for pregnant/lactating women and malnourished individuals suffering from HIV or tubercolosis, and Super Cereal plus (SCp) designed for children aged 6-59 months (WFP 2019). SCp is prepared by dry-blending heat-treated cereal, dehulled soybean, sugar and skim milk powder (8%, w/w), and supplementing with refined soybean oil, vitamins, and minerals (WFP, 2015). Depending on the cereal source, SCp has three subcategories, namely Super Cereal plus wheat soya blend (SCpWSB), Super Cereal plus corn soya blend (SCpCSB) and Super Cereal plus rice soya blend (SCpRSB). All are reconstituted (16.7% dry matter) and cooked to a soup or porridge prior to consumption.

Food composites (e.g., from cereal, dairy and legume), such as FBF, combine the additive nutritional, textural and sensory functionalities of the constituent food groups. Consequently, fermented milk-cereal beverages are being increasingly promoted for their nutritional benefits. The inclusion of milk solids in FBF enhances the content of important nutrients, including essential amino acids, linoleic acid, fat-soluble vitamins (vitamin A, α-tocopherol), calcium (Ca) and phosphorous (P). Cereal imparts viscosity/texture to the reconstituted FBF, and enhances the content of soluble dietary fibre, including β-glucan. Research suggests that β-glucan in the human diet reduces glycaemic index, blood cholesterol and the incidence of coronary heart disease, and improves gastrointestinal function. However, phytic acid (inositol hexakisphosphate), which is present in cereals, chelates cationic metals including iron (Fe), zinc (Zn) and Ca, reduce their absorption in the gastrointestinal tract, and increase the risk of mineral deficiencies.

The current project focused on the development of an alternative process (to that used for SCp) for the manufacture of FBF with enhanced nutritional characteristics from Irish cereals and dairy ingredients. Key strategies applied to enhance the nutritional quality included:

(i) increasing the proportion of milk solids relative to cereal; (ii) the use of fermented milk, rather than milk/milk powder, to enhance the content of bioactive compounds and B vitamins, and reduce the level of lactose; (iii) parboiling the cereal in excess water at ~ 100 °C for ~ 70 min to reduce phytic acid content; (iv) and co-fermentation of the fermented milk-cereal blend to enhance the activity of endogenous cereal phytase which hydrolyses phytic acid and reduce its cation-chelating ability.

2. Questions addressed by the project:

- Can FBF, complying with the minimum compositional and consistency specifications of SCp (WFP, 2015), be developed by co-fermentation of a wet blend of fermented milk and parboiled cereal?
- What are the critical factors affecting the nutritional composition of the FBF?
- How can the phytic acid content of FBF be reduced?
- How stable is FBF when stored at different temperatures?

3. The experimental studies:

- Benchmarking analysis of commercially-available milk-cereal blends including SCpCSB, Kishk and Tarhana. The latter (Kishk and Tarhana) are dried fermented milk-/cereal-based products traditionally consumed in the Middle East and Balkan Peninsula respectively, where they are reconstituted and cooked to form porridge or soup, or used as an ingredient in savory and sweet dishes. All products were assayed for composition, water-sorption behavior, colour, and reconstitution characteristics (gelatinization temperature, water holding capacity, pasting behaviour, flow behavior on shearing, and flow).
- Assessing the effects of altering selected experimental parameters on the properties of FBF: ratio of milk solids-to-parboiled cereal solids; mill size, cereal type; and co-fermentation time of the fermented milk-cereal blend prior to drying.
- Based on the information from the foregoing, optimization of the process for the pilot-scale manufacture of FBF.
- Evaluating the impact of storage time and temperature on changes in gross composition, sugars,

Contact Tim Guinee Email: tim.guinee@teagasc.ie

lactic acid, colour, and reconstitution behaviour of the developed FBF.

4. Main results:

Benchmark analysis of commercially-available fermented milk-cereal

Compared to SCpCSB, Kishk and Tarhana had lower mean contents of dry matter, protein, fat, Ca, magnesium (Mg), Fe and Zn, and higher contents of starch, lactose, lactic acid and salt. Kishk and Tarhana also differed significantly, with the former having higher mean levels of protein, fat, lactose, lactic acid, Ca, Mg, Fe and Zn, and lower values of starch, salt and pH. Despite the compositional differences, all products had similar water-sorption behaviour at 5 -85% relative humidity. On reconstitution (16.7 % dry matter), Tarhana had notably higher values of water holding capacity (WHC), viscosity during pasting and cooling, yield stress (σ_0), consistency coefficient (K), and viscosity on shearing from 20 to 120 s^{-1} at 60°C (η_{120}) than SCpCSB or Kishk. The results suggested that the production of an FBF product that simulates the minimum nutrient values and consistency of SCpCSB more closely (WFP, 2015), than Kishk or Tarhana, would necessitate and increase in protein content, reduction in starch content, and fortification with vitamins/minerals

Effect of selected parameters on the properties of FBF.

- *Ratio of fermented milk-to-parboiled wheat*

  The study was undertaken to evaluate the effect of increasing milk solids from ~ 20 to 39%, while simultaneously reducing cereal solids from ~ 75 to 54% (w/w); this was achieved by altering the ratio of fermented milk (FM)-to-parboiled wheat (PW) from 1.5 to 4.0 during formulation. Increasing the FM:PW ratio from 1.5 to 4.0 resulted in increases in protein (15.2–18.9%), fat (3.7–5.9%), proportions of stearic (C18:0) and oleic (C18:1, n9) acids, vitamin A, β-carotene, α-tocopherol, lactose (6.4–11.4%), lactic acid (2.7–4.2%), Ca, Mg and P. Conversely, it resulted in lower contents of γ-linolenic acid (C18:2, n6), starch, phytic acid and β-glucan. Consistent with the reduction in starch content, increasing the FM:PW ratio led to lower values of pasting viscosity, σ_0, K, η_{120} and flow of the reconstituted FBF. The results indicated that FBF with a FM:PW ratio of 4:1 complied with the compositional specifications of SCpCSB for dry matter (≥ 93%), (fat ≥ 9%), protein (≥ 16%) and flow (100 mm/30 s at 46 °C for the reconstituted FBF with 16.7% dry matter).

- *Co-fermentation time*

  Fermented milk, FM (pH 4.6) and parboiled wheat, PW, were blended and co-fermented for 0 to 72 h at 36 °C prior to drying and milling. Increasing co-fermentation time from 0 to 24 h significantly reduced the phytic acid content of the resultant FBF by 40%, i.e., from 0.87 to 0.53 % (w/w). However, further prolongation of fermentation time from 24h to 48 or 72 h did not affect phytic acid content. Altering the pH of the FM at blending (with the parboiled what) from 4.2 to 5.6 showed that the reduction in phytic acid content during the first 24 hour of co-fermentation could be elevated to 60% by raising the pH of the FM from 4.6 to 5.0, suggesting a pH-dependence of the endogenous wheat phytase. Otherwise, increasing co-fermentation time from 0 to 72 h resulted in FBF with lower lactose and pH, and higher contents of lactic acid and galactose. Simultaneously, the values for pasting viscosity, σ_0, K, and η_{120} decreased with co-fermentation time, while flow increased.

- *Cereal type*

  FBF was made using parboiled oats (*Avena sativa*, cv.Barra; FBFo), wheat (*Triticum aestivum*, cv. Sparrow; FBFw) or barley (*Hordeum vulgare*, cv. Propino; FBFb). Cereal type significantly affected the composition and reconstitution behaviour of the reconstituted FBF. Most notably, FBFo had higher contents of β-glucan, phytic acid, starch, fat, Fe, Zn, Se (selenium) and Mo (molybdenum), a higher ratio of amylose-to-amylopectin, and lower levels of lactose and lactic acid, than FBFw or FBFb. On reconstitution and cooking, FBFo underwent less starch granule rupture (lower soluble starch), and had higher values of WHC, pasting viscosity, σ_0, K and η_{120}, and lower flow, than FBFw or FBFb. Overall, the consistency of the cooked FBF varied from porridge-like for FBFo to soup-like for FBFw and FBFw. The study indicated that starch content and amylose (as a proportion of total

Contact Tim Guinee Email: tim.guinee@teagasc.ie

starch) are key factors controlling the consistency of reconstituted FBF when formulating to defined protein content. The contents of dry matter, protein, fat, and elements in all FBFs complied with the minimum levels specified for SCp; a similar trend was observed for consistency of the reconstituted FBFw and FBFb, but not in the case of FBFo for which the flow was less than that prescribed for SCp (WFP, 2015).

- Extent of milling

  Fermented milk, FM (pH 4.6) and parboiled wheat, PW, were blended, co-fermented, and dried to ~ 94% dry matter. The resultant 'cake' was milled using an Ultracentrifugal Mill (ZM 200, Retsch) fitted with ring sieves with trapezoid holes of 0.5, 1.0, 1.5, 2.0, and 3.0 mm aperture. It was considered that mill size may affect the hydration of starch granules during co-fermentation, and hence, the pasting and rheological behaviour of the resultant FBF. However, mill size did not significantly affect any of the measured parameters.

Effect of storage conditions

FBF was formulated using wheat, oats or barley, vacuum-packed in 200 g quantities in PE60/Met shrink pouches, and stored at 15, 30 or 37°C for 18 months, and analyzed at 2 month intervals. Storage significantly affected the composition, colour and reconstitution properties of FBFs to an extent dependent on cereal type used in formulation and the duration and temperature of the storage period. Storage-related changes included reductions in whiteness (L* colour co-ordinate) and concentrations of lactose, galactose, lactic acid and lysine, and increases in the redness (a*) and yellowness (b*) of the FBF powders. Simultaneously, the water holding capacity and pasting viscosity of the reconstituted FBF decreased while the flow increased. FBFs stored at 15°C were overall quite stable over the 18 month storage period. Conversely, storage at 37°C coincided with rapid deterioration in colour, WHC and viscosity at storage times of ≤ 4 months. It was postulated that the changes in colour were most likely due to Maillard reactions, while the reduction in water binding capacity and pasting viscosity of the reconstituted FBF was due to changes in starch structure consequential with the oxidation of cereal proteins and hydrolysis of fat.

Recommended process for the manufacture of FBF

The recommended process comprised a series of steps: de-hulling, parboiling and milling cereal; blending fermented milk (~ 16.8% dry matter, DM; pH 5.0) and parboiled cereal (~ 94% DM) at a weight ratio of 2.9 to 4.4:1 (depending on the protein content of the cereal), co-fermentation of the blend at 35 °C for 24 h, shelf-drying at 46 °C to a cake, breaking and milling the cake to a base powder with a mean particle size of < 1 mm, fortification of the base powder with vitamins, minerals and essential free fatty acids, vacuum packing the FBF in PE60/Met shrink pouches, and storage at 15 °C for ≤ 18 months.

5. Opportunity/Benefit:

The generated data provide new knowledge and insights on the manufacture of FBF prepared from fermented milk and parboiled cereal, and how its characteristics are affected by formulation, manufacturing process and storage conditions. This knowledge is applicable equally to the formulation of other combined dairy and cereal-based foods/beverages with points of differentiation suited to different markets. FBF presents a new export opportunity for the manufacturers of dairy ingredients and cereals.

6. Dissemination:

Main publications:

O'Callaghan Y.C., Shevade A.V., Guinee T.P., O'Connor, T.P., and O'Brien N.M. (2019). Comparison of the nutritional composition of experimental fermented milk: Wheat bulgur blends and commercially available Kishk and Tarhana products. *Food Chemistry* **278**:110–118.

Shevade A.V., O'Callaghan Y.C., O'Brien N.M., O'Connor T.P. and Guinee T.P. (2018). The proportion of fermented milk in dehydrated fermented milk-parboiled wheat composites significantly affects their composition, pasting behaviour, and flow properties on reconstitution. *Foods* **7**:113 (1-16).

Shevade A.V., O'Callaghan Y.C., Kennedy D., O'Brien N.M., O'Connor T.P. and Guinee T.P. (2019). Development of a fortified blended food base from fermented milk and parboiled wheat, and comparison of its composition and reconstitution behaviour with those of commercial dried dairy-cereal blends. *Food*

Science and Nutrition **7**: 1-11.

Shevade A.V., O'Callaghan Y.C., Kennedy D., O'Brien N.M., O'Connor T.P. and Guinee T.P. (2019). Cereal type significantly affects the composition and reconstitution characteristics of dried fermented milk-cereal composites. *Journal of the Science of Food and Agriculture* **99**:3097-3105.

Shevade A.V., O'Callaghan Y.C., Kennedy D., O'Brien N.M., O'Connor T.P. and Guinee T.P. (2019). Fortified Blended Food Base: Effect of co-fermentation time on composition, phytic acid content and reconstitution properties. *Foods* **8**: 388 (1-14).

Shevade A.V., O'Callaghan Y.C., Kennedy D., O'Brien N.M., O'Connor T.P. and Guinee T.P. (2019).Changes in colour, water holding capacity and pasting behaviour of fortified blended foods made from different cereals on storage at different temperatures (*Journal of Food science and Technology*, submitted September 2019).

Popular publications

O'Brien N.M., O'Connor T.P. and Guinee T.P. (2015). Fortified blended foods using Irish ingredients. TResearch. 10(4):30-31.

O'Brien N.M., O'Connor T.P. and Guinee T.P. (2019) Blending dairy and cereal. TResearch. 14(3): 30-31.

7. Compiled by: T. P. Guinee

Contact Tim Guinee Email: tim.guinee@teagasc.ie