



Flow Behaviour of Vegetable Beverages to Replace Milk

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Abstract. Recently, milk consumption has been declining and there is a high demand for cow milk substitutes other than soy beverages. However, market offers are mainly cereal and nut-based beverages, which are essentially poor in protein content (less than 1.5% against the 3.5% in milk) and are not true milk replacers in that sense. Therefore, legume-based beverage was becoming a fast-growing segment in newer food development. This work presents the rheological behavior of commercial non-dairy beverages, showing that they are shear-thinning fluids and it is part of a database containing all information available about commercialized nondairy alternative beverages that is being collected to be used as the target for the development of pulse-based beverages. Flow properties of pulse-based beverages are expected to be typical non-Newtonian fluids, as current non-dairy alternative beverages, where the apparent viscosity decreases over shear, i.e., they are shear-thinning fluids which is fundamental for the mouth feel and consumer acceptance of new developing beverages. The viscosity curves obtained are presented as a guide flow pattern to be achieved by the use of rheology modifiers, if necessary, to find the right mouth feel.

1 Introduction

Although the milk segment is projected to account for the largest market share during the forecast period of 2018-2023, the market for dairy alternatives is projected to grow from USD 17.3 billion in 2018 to USD 29.6 billion by 2023, at a Compound Annual Growth Rate (CAGR) of 11.4%, and Asia-Pacific region represents the biggest market share [1, 2]. This growth is due to three main factors: (i) nutritional benefits offered by plant-based dairy alternatives, such as to reduce the cholesterol level, to improve cardiovascular health, and diabetes control [3]; (ii) the growing consumer preference for vegan diets; and (iii) increasing cases of lactose intolerance and milk allergies [4–6]. The resulting response from the Industry, so far, is the offer of cereal and nuts based beverages, such as those made from rice, almonds or oat that are lower in protein (<1.5%) than milk (3–4%) [7]. Legume-based beverages, such as those made from soy, can contain added vitamins and minerals and they contain a similar level of protein to

milk (minimum 3%). Soy milk is still the most widely consumed non-dairy beverage, but has been decreasing its share because of health concerns related to GMO and allergens, high levels of isoflavones and with CO₂ footprint. The major issue that is hampering the production of legume-based beverage is the “beany” flavor, associated to endogenous lipoxygenases which oxidize unsaturated fatty acids in oil rich pulses like soy [8] and peanuts (over 20% fat), but should be less pronounced in pulses like peas, lupins or chickpeas (1.5 to 5% fat). The activity of the lipoxygenases is enhanced by the presence of polyphenols (bitter taste), but is suppressed by processing techniques like soaking, germination and pressure-cooking [9].

This work presents the rheological behavior of commercial non-dairy beverages and it is part of a database containing all information available about commercialized nondairy alternative beverages that is being collected for comparison to nutritional, rheological, physical and sensorial characteristics of the pulse-based beverages. This study aims to find a viscosity pattern to use as a guide to adjust the flow of legume-based beverages to be developed.

2 Materials and Methods

2.1 Material

Skimmed milk and eight different UHT non-dairy beverages were commercially acquired and stored at room temperature, until analysis: almond milk, oat milk, hazelnut milk, coconut milk, quinoa milk, nut milk, dry nuts milk and rice milk.

2.2 Rheological Measurements

Rheological measurements were performed using a controlled-stress rheometer (Haake MARS III, Germany), at 20 ± 1 °C. A serrated parallel plate, with 60 mm geometry, to avoid sample sliding was used, and the distance between plates was set at 0.25 mm, at 20 °C. The steady-state measurements were performed for viscosity curves determination, repeated three times for skimmed milk and each non-dairy beverage.

2.3 Statistical Analysis

Statistical analysis ANOVA One-Way, Means comparisons -Tukey Test, was performed using the software OriginPro version 8, to adjust flow curves to Power Law (Oswald-de-Waele) model to the shear-thinning region of the curves. The significance level was set at 95%.

3 Results and Discussion

3.1 Comparison of Skimmed Milk and Non-dairy Beverages

Non-dairy beverages evidenced typical non-Newtonian flow, where the apparent viscosity is decreasing over shear, i.e., they are shear-thinning fluids (Fig. 1).

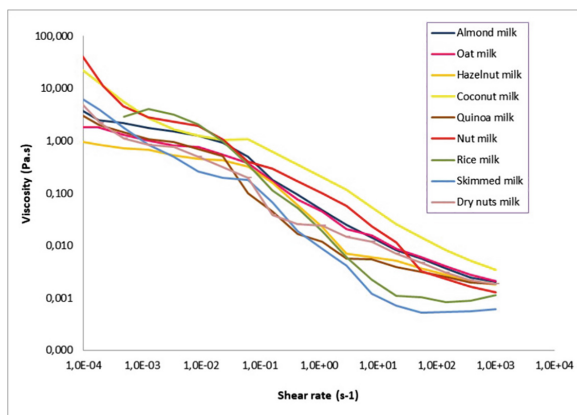


Fig. 1. Viscosity curves for the skimmed milk and the eight non-dairy beverages studied.

The skimmed milk and the beverages' consistencies were similar and varied between 0.014 and 0.065 Pa.sⁿ (Table 1). Skimmed milk and rice beverage were the ones with the lowest value of consistency. The coconut evidenced a higher consistency of 0.358 Pa.sⁿ which may be explained by the addition of rheology modifiers (higher amounts of gums added).

Table 1. Power Law model fitting results. (*corresponds to a significant different value at $p < 0.05$)

| Samples | K (Pa.s ⁿ) | n |
|-------------------|------------------------|---------------|
| Skimmed milk | 0.014 ± 0.006 | 0.375 ± 0.050 |
| Oat beverage | 0.052 ± 0.021 | 0.246 ± 0.117 |
| Almond beverage | 0.065 ± 0.010 | 0.457 ± 0.049 |
| Hazelnut beverage | 0.047 ± 0.010 | 0.473 ± 0.031 |
| Coconut beverage | 0.358 ± 0.025* | 0.262 ± 0.011 |
| Quinoa beverage | 0.026 ± 0.006 | 0.470 ± 0.060 |
| Nut beverage | 0.038 ± 0.005 | 0.592 ± 0.029 |
| Dry nuts beverage | 0.038 ± 0.004 | 0.439 ± 0.054 |
| Rice beverage | 0.008 ± 0.005 | 0.390 ± 0.031 |

As regards flow index, oat and coconut beverages presented the lower values, around 0.25. The skimmed milk and rice beverage showed “n” values around 0.38 and there is a third group of beverages which evidenced a higher flow index (0.439–0.592), not showing a correlation with its corresponding compositions.

From the resumed Table 2 of these beverages composition one can find that the protein content is from 0.1 to 0.8% (w/v), way far from the skimmed milk content of 3.5%.

Table 2. Skimmed milk and non-dairy beverages relevant composition (package labels).

| Samples | Protein (% w/v) | Hydrocolloids | Sugars |
|-------------------|-----------------|---------------|--------|
| Skimmed milk | 3.5 | No | No |
| Oat beverage | 0.2 | Yes | No |
| Almond beverage | 0.5 | Yes | No |
| Hazelnut beverage | 0.4 | Yes | Yes |
| Coconut beverage | 0.1 | Yes | No |
| Quinoa beverage | 0.8 | Yes | No |
| Nut beverage | 0.2 | Yes | No |
| Dry nuts beverage | 0.6 | Yes | Yes |
| Rice beverage | 0.1 | No | No |

The lack of protein is compensated by the addition of hydrocolloids, and sometimes even sugar, to produce these beverages with acceptable mouth feel viscosity. This is a good example of the use of rheology modifiers and a bad example of nutritional replacement, that does not justify the higher market price of these vegetable beverages, when compared to milk.

4 Conclusions

Viscosity profiles of the vegetable beverages and skimmed milk were all shear thinning and showed extensive overlapping, which is an indication of the correct mouth feel target. This was attained by the use of rheology modifiers (added gums) to replace the protein effect of milk. The viscosity curves hereby presented will be used as a guide flow pattern to be achieved by the use of pulses to develop alternative beverages to milk, with similar protein content, to find the right mouth feel in the future legume-based beverages.

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