MRI of aerated beverages: intragastric behaviour and role in hunger suppression

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Target Audience: Gastrointestinal MRI specialists, nutritionists and dieticians, scientists with an interest in gastric emptying, weight-control meal replacement shakes industry.

Introduction: Obesity is a global problem and is a result of several factors, including an abundance of energy-dense meals which have low satiety value. The physical properties of meals such as volume, whether liquid or solid, palatability and energy density all influence appetite. It has been shown that entrapping large volumes of water or air into food may be a desirable approach to designing products with the ability to satiate with reduced calorie density[1]. Previous studies on aeration have shown that aerated meals taken as meal replacement shakes and in the context of reduced-energy diets, reduced appetite and improved satisfaction with diet[2-3]. Aeration shows evidence of increasing satiety more than non-aerated meals, but the mechanisms whereby this occurs have not been demonstrated. This study therefore aimed to use MRI to test the hypothesis that gastric-stable foams produce more sustained gastric distension and hunger reduction than less stable foams.

Methods: The study was performed using a 1.5T Philips Achieva Scanner with a 16-element SENSE torso coil. Eighteen healthy males were fed three skimmed milk-based test products (all 110 kcal) in a randomised, balanced, crossover trial. These were a non-aerated beverage (liquid control, LC; 140 ml), and two beverages aerated to foams by whipping, one stable in the stomach (stable foam, SF; 490 ml), and one less stable in the stomach (less stable foam, LSF; 490 ml). Gastric volumes (foam, air, liquid) were measured using a bTFE sequence (TE/TR 1.4/2.8 ms, reconstructed resolution 1.56 x 1.57 x 10 mm^2, FA 80^o) which acquired 30 transverse slices 5 mm thick, in a single 12 second breath-hold. Self-reported appetite ratings were collected after each scan and quantified by AUC or Time-To-Return-To-Baseline (TTRTB)[4].

Data Analysis: The volumes of bulk liquid layer, foam layer and air layer in the stomach were measured by tracing manually a region of interest around each area (Figure 1) using Analyze 9.0 (Biomedical Imaging Resource, Mayo Foundation, Rochester, MN) and summing the volume across the slices. The intra-operator variability was found to be <5% for 3 subjects evaluated 4 times. For appetite questionnaires, the time course of the mean score of each question was plotted and the area under the curve (AUC) was calculated. TTRTB was calculated using the Weibull modelling technique[4].

Results: Both foams caused significantly increased gastric volumes and slowed gastric emptying. The aerated beverages both reduced hunger (all $P<0.001$) compared to LC (Figure 2), but there was no statistical difference between the two foams. Compared to LSF, SF further produced a significantly slower decrease in total gastric content ($P<0.05$) and foam volume ($P<0.0001$), and a longer TTRTB (248 vs. 197 min; $P<0.05$), though hunger AUC values were not statistically different. There was a modest but significant negative correlation between total gastric volume and hunger scores, particularly 10 min after ingestion ($r = -0.5$, $P<0.0001$).

Conclusions: This study provided novel mechanistic insights on the intragastric behaviour of aerated beverages and their role in hunger suppression. The foam layer was clearly visualized in the stomach. The data suggests that the hunger suppression induced by foams can largely be explained by effects on gastric volumes and emptying. Those effects may be further enhanced by foam stability. Improved knowledge could help design new products aimed for the weight-control market.

References: [1] Aguilera. Journal of Food Engineering 2005;67:3-11. [2] Melnikov et al. Obesity 2014;22:2131-6. [3] Peters et al. Int J Obesity 2014; DOI: 10.1038/ijo.2014.151. [4] Schuring et al. Appetite 2012;59:601-9.

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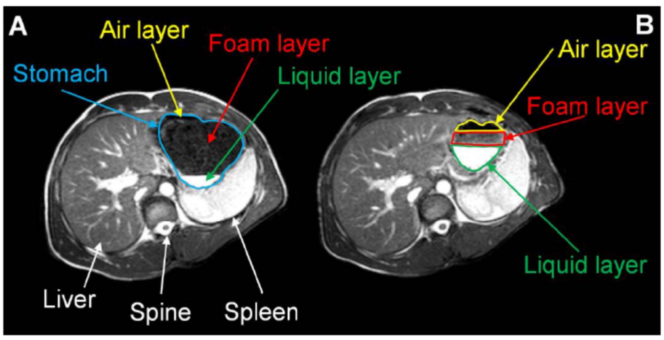

__Figure 1__: Representative example of axial MRI images through the same location in the abdomen of a volunteer who ingested a stable foam (SF) aerated beverage. (A) was acquired 10 minutes and (B) 90 minutes after ingestion

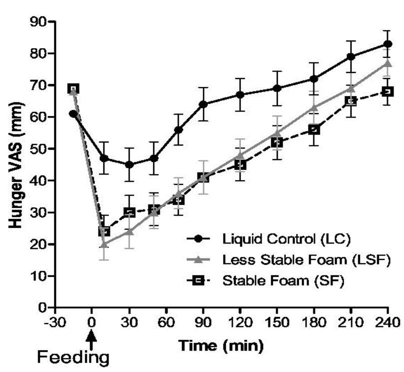

__Figure 2__: Perceived hunger electronic visual analogue scores (EVAS) collected for 18 volunteers throughout the study days