Effect of fat emulsion acid stability on gastric emptying, CCK release and satiety: an EPI study

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Background: Consumption of pre-processed foods high in fat, often added as a fat emulsion, is steadily increasing in the developed countries. Fatty foods are high in energy density, have high palatability and may lead to lipid calorie over-consumption. Manipulating the sense of satiety derived from a fatty meal requires knowledge of the gut-brain interactions. One of the main mechanisms triggered by ingestion of fat is the release of cholecystokinin (CCK) from the proximal small bowel [1].

Aim: Based on our previous work on fat emulsions [2], the aim of this study was to investigate whether it would be possible to manipulate intragastric distribution and hence gastric emptying, CCK levels and satiety feelings in healthy volunteers by simply modifying the intragastric acid stability of the fat emulsions fed to them.

Materials and Methods: Nine healthy male volunteers, free from serious disease and within ± 25% of ideal body weight, attended on 2 separate days, having fasted overnight. After intravenous cannulation, they were fed 500 mL of one of two olive oil-in-water emulsion test meals that have equal fat content (675kcal) and equal droplet size distributions, but opposite acid stability. One stays intact when exposed to the stomach acidic conditions (the "acid-stable") and the other (the "acid-unstable") breaks rapidly into a floating layer of oil and an underlying aqueous phase when acidified. At t= 5 hours the subjects ate a standard soup meal. Breath held single-shot EPI images (in-plane resolution 3.5 mm x 2.5 mm and slice thickness 1 cm) were acquired in 130 ms on a whole-body 0.5 T purpose-built EPI scanner, 128x128 matrix and effective echo time 40 ms. At intervals, a transverse rapid multi-slice set was acquired from the heart to the kidneys to visualise the gastric lumen. Inversion recovery and spin-echo images were also acquired on a single slice positioned on the stomach body to help visualising the fat spatial distribution. In between scanning, subjects were asked to sit upright. The volunteers' sense of fullness, appetite and hunger was monitored hourly for 10 hours using self-assessment satiety score questionnaires. Blood samples, collected into EDTA chilled tubes containing 5000 KIU aprotinin, were cooled in an ice-bath immediately. Plasma was separated by centrifugation and stored at -70 °C until assayed. CCK concentrations were measured by commercial radioimmunoassay. This protocol was approved by the local Ethics Committee and volunteers gave informed written consent prior to experiments. Data are expressed as mean±SEM. 2-tailed Wilcoxon signed rank test for paired comparisons and Pearson's product moment correlation r were used.

Results: The gastric half-emptying time (T50%) of the acid-unstable emulsion was faster than the acid-stable emulsion meal, Wilcoxon's $p<0.008$ (Fig. 1). Fig. 2 shows the average CCK plasma levels with time for both meals. The acid-stable emulsion released more CCK than the acid-unstable one for up to 7 h. *$p<0.05$ at individual time points t=1, 1.5 and 4 h and $p<0.001$overall the whole 10 h experiment. Fig. 3 shows the volunteers' % sense of hunger as a function of plasma CCK levels at corresponding time points for both the acid-unstable (□) and the acid-stable (●) emulsions. An overall exponential correlation between decreasing hunger with increasing CCK was found ($r=0.91$) with the acid-stable emulsion being associated with greater satiety and higher CCK levels. The % fullness linearly increased with increasing CCK ($r=0.82$) and the % appetite decreased exponentially with increasing CCK ($r=0.61$).

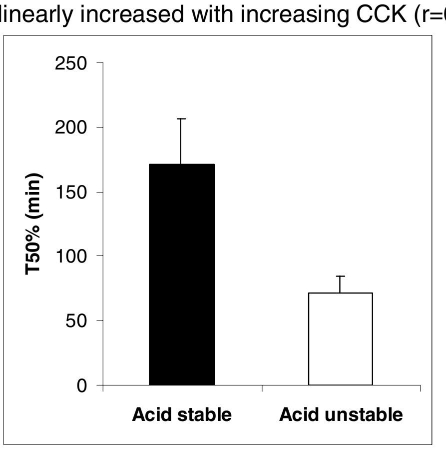

Figure 1

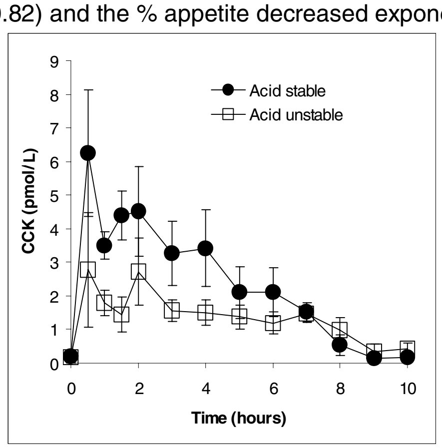

Figure 2

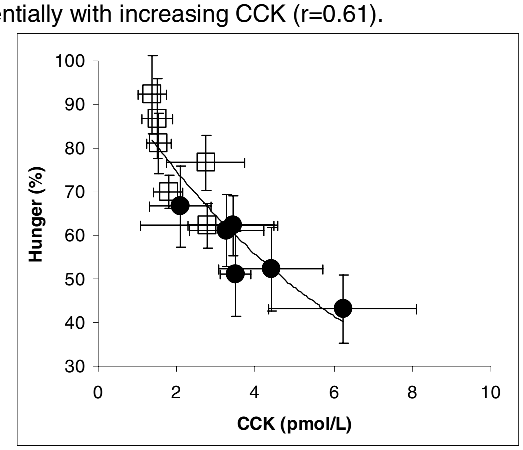

Figure 3

Discussion: We hypothesised that altering the fat stability of emulsions by using different emulsifiers could induce significant changes in the gastric emptying, CCK and satiety response. We were able to confirm that, when compared with an equicaloric acid-unstable emulsion, acid-stable emulsion slowed gastric emptying by about 2.5 fold, increased the levels of circulating CCK and increased the sense of satiety. The treatment of obesity by dietary means has many advantages over surgical and pharmaceutical approaches. Modifying food production methods to alter the post-prandial delivery of fat to the intestine, the gut peptides response and, ultimately, satiety mechanisms, might be even more effective.

References:

[1] Liddle RA. Regulation of cholecystokinin secretion in humans. J Gastroenterol 2000;35:181-187.

[2] Marciani L et al. Intragastric oil-in-water emulsion fat fraction measured using inversion recovery echo-planar magnetic resonance imaging. J Food Sci 2004;69:E290-E296.