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Use of satiety peptides in assessing the satiating capacity of foods ☆

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ABSTRACT

Foods differ in their satiating capacity. Satiety peptides may help to provide evidence for biological mechanisms behind these differences. The aim of this paper was to discuss the physiological relevance of three individual appetite peptides, i.e. CCK, GLP-1 and PYY, in assessing the satiating capacity of foods. A literature research was conducted on CCK, GLP-1, PYY and satiety; effective exogenous infusion studies and endogenous production studies, i.e. changes induced by foods, were identified. The relative changes in blood concentrations in these studies were compared in order to assess an indication of the physiological relevance of the peptides. Relative changes in the two types of studies investigating CCK overlapped, i.e. increases in serum were 3 to 14-fold in effective exogenous studies (n = 7) and 2 to 8-fold in endogenous production studies (n = 9). The relative changes in GLP-1 and PYY did not overlap; GLP-1: 4 to 16 fold in effective exogenous studies (n = 4) and no effect to 4 fold in endogenous production studies (n = 38). PYY: 3 to 11-fold in effective exogenous studies (n = 14) and no effect to 2-fold in endogenous production studies (n = 10). GLP-1 and PYY show effects on satiety at supra-physiological dosages, they are not likely to contribute individually to a difference in satiating capacity of foods and can therefore not be interpreted in isolation. The effects of CCK are likely to be in the physiological range and therefore may have an individual contribution to a difference in satiating capacity between foods.

1. Introduction

Foods differ in their satiating capacity; foods with similar volume and energy density have different effects on appetite. For example, protein, carbohydrates and fat content have hierarchical effects on satiety in the order of protein > carbohydrate > fat [1]. Various studies have investigated the satiating efficiency of certain types of dietary fibres, proteins, carbohydrates and bioactive components (see for example [2–5]). The last decade the numbers of articles published about “satiety” and “food” more than doubled, i.e. from 82 in 1999 to 182 in 2009 (Scopus, Elsevier, 2009).

The golden standards for measuring the effects of food properties on appetite are ratings made on visual analogue scales and/or the direct measurement of food intake [6,7]. However, biochemical measurements, such as the so-called satiety peptides that are causally involved in appetite regulation, may help to provide evidence for a biological mechanism behind differences in satiating capacity [8,9]. The most frequently studied anorexic peptides in the food satiety field are CCK, GLP-1 and PYY [8–10].

The evidence for a causal role in the regulation of appetite mainly comes from clinical studies. Typically in these studies, synthetic peptides are exogenously administered to subjects by means of an infusion or injection. Before, during and after infusion, appetite is measured, i.e. appetite ratings at several time points and/or ad libitum food intake after a fixed period of time. Subsequently, appetite is compared to that after administration of a placebo (saline). In the rest of this manuscript we refer to this type of studies as “exogenous administration studies”.

The studies investigating the effect of the foods (or their components) on appetite are mostly studied in so-called test meal designs. In this type of studies, before, during and after consumption of a fixed amount of the test meal, also called a pre-load, serum concentrations and appetite are measured. These measures are then compared to the same measurements after consumption of a reference product. These are studies to which we further refer as “endogenous production studies”.

One of the main questions in the food satiety field is whether or not differential changes in satiety peptides are a reflection of the different satiating capacity of food (components). The objective of this paper is to discuss the physiological relevance of three individual appetite peptides in assessing the satiating capacity of foods, i.e. the

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satiety peptides CCK, GLP-1 and PYY. We did this by comparing the changes in blood concentrations between exogenous infusion studies and endogenous production studies. In other words, we investigated whether the relative change in blood levels between the two types of studies overlaps, this in order to judge whether the exogenous effects are within the physiological range. Hereby presuming that the changes that can be accomplished by foods should be in the physiological range.

2. Materials and methods

In order to find recent original studies on this topic, a systematic search was conducted. Silverplatter Medline databases issued between October 2003 and December 2009 were accessed. Only articles in English were selected. Moreover the paper should contain original data; reviews, comments and case-reports were not selected.

The search used for appetite-related behaviour included the following search terms: (energy intake) or (intake) or (energy) or (satiation) or (satiety response) or (eating) or (hunger) or (appetite regulation) or (appetite). This search was then combined with a search term for each of the peptides, i.e. CCK, GLP-1, PYY and their synonyms.

Articles were selected based on the title and abstract and, if relevant, the article was ordered and added to the tables. A prerequisite to be selected in the analyses was that the study focused on appetite, i.e. satiation (ad libitum meal intake) or satiety (subjective appetite responses or ad lib food intake of a second meal in a pre-load setting).

Additionally, references of the relevant articles were checked by means of the data-base Scopus® (Elsevier BV, 2009), which has the possibility to check both backward (referring to) and forward (being referred to).

We classified the studies into two groups: 1) exogenous administration studies, i.e. studies that investigated the effect exogenous infusion of the satiety peptide on peptide concentrations in blood and on appetite related behaviour (Table 1), and 2) endogenous production studies, i.e. studies that investigated the effects of food (components) on peptide concentrations in blood (Table 2). Only studies that were randomised, cross-over, and single or double blind were included. We included only studies conducted in healthy adults with a BMI within the normal range, and with a habitual diet as background diet. For the endogenous production studies, we only included studies that used a fixed or standardised meal which provided at least 1 MJ. Moreover, baseline and peak concentrations in blood should have been available.

For each study, per treatment, relative changes in peptide concentrations were calculated, i.e. ratio's. This was done by dividing the peak levels by the baseline peptide concentration. If numbers were mentioned in the text, these were used. If not, the ratio was extracted from the figures by means of a pdf-measurement tool (Adobe Acrobat Pro 9.0, New Jersey USA). This tool allows you to measure the distance between two points in a pdf-document at 0.1 mm accuracy.

3. Results

3.1. CCK

We identified 7 trials that investigated the effect of exogenous CCK on serum CCK concentrations and satiety. Seven out of 8 treatments were effective in either decreasing energy intake or decreasing appetite sensations. Effective dosages of CCK increased concentrations in a range from 3 to 14-fold compared to baseline; the median increase was 5-fold (Table 1).

Nine studies that investigated the effect of foods on serum CCK concentrations were included; in total these studies investigated 20 foods. Seven of these endogenous studies measured appetite sensations or/and ad libitum intake after ingestion of the food compared to a reference food (Table 2). Ingesting foods increased serum concentrations with a range from 2 to 8-fold. The median increase compared to baseline was 3-fold.

Fig. 1 illustrates the range of changes in the exogenous and endogenous studies. From the figure it can be seen that the ranges of both study-types overlap.

3.2. GLP-1

Eight studies were found that measured the effect of exogenous GLP-1 administration on blood GLP-1 concentrations and satiety (Table 1). Four of these studies showed an effective effect on either energy intake or appetite sensations. Moreover, in one of the studies a clear dose response relationship was found on blood concentrations [11]. Effective dosages increased blood concentrations from 4 to 16-fold compared to baseline, the median of all treatments was 8-fold.

We included nine experiments that investigated the effect of foods on serum GLP-1 concentrations; in total 38 foods were studied in these experiments. In all nine endogenous studies, satiety, i.e. appetite sensations or ad libitum intake, was measured. Effects compared to the reference food are shown in Table 2. Blood concentrations were increased by foods within the range 1 to 4-fold. The median change was 2-fold.

Fig. 1 shows that the changes in blood concentrations from effective dosages in exogenous administration studies do not overlap with those of the endogenous production studies.

3.3. PYY

We identified 7 studies that investigated exogenous administration of PYY (Table 1). Two of these studies studied different origin of PYY; Le Roux [12] studied different commercial producers of synthetic PYY. Sloth [13] studied two different molecular forms of PYY, i.e. PYY_{1-36} and PYY_{3-36}. Le Roux et al. [14] studied six dosages ranging from 0.2 to 0.8 pmol/kg/min. In total 19 different treatments were tested in the 7 exogenous studies; 14 of these treatments were effective in either lowering appetite sensations or decreasing energy intake in a second meal. In these effective studies the relative changes in blood concentrations ranged from 3-fold to 11-fold; the median change was 6-fold.

Five endogenous studies were included (Table 2). In total 10 different test foods were investigated in these studies; the energy content of the foods varied from 1 to 12.6 MJ. Three studies measured satiety. The relative change in blood concentrations varied from no change at all to a 2.3 fold change.

Fig. 1 shows that the increase in serum levels in exogenous studies does not overlap with the changes induced by foods.

4. Discussion

The objective of this paper was to discuss the physiological relevance of three individual appetite peptides in assessing the satiating capacity of food (components). The studies that investigated effective dosages of exogenous CCK infusion showed relative changes in that are within the physiological range, i.e. they overlap with the effects of foods. For GLP-1 there is less overlap and for PYY there is even a gap between the two study types. The effects that were found with exogenous administration of these peptides are presumably supra-physiologic; the increases in blood levels were larger than can be evoked by foods.

In the current paper, we studied the effects of both exogenous administration and endogenous production on blood concentrations of satiety peptides. We did this by comparing two different types of studies with different aims, i.e. a clinical and a food based aim. We realise that there are several limitations to this. We calculated our outcome variable as the peak level compared to baseline, i.e. the relative increase to baseline concentrations. We did this in order to rule out effects of the method by which the peptides are measured. Different methods are available to measure appetite concentrations, these methods have in common that the concentrations are based on the proportional differences in a certain