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Viewpoint

The pleasure response to palatable foods, notably those rich in sugar and fat, may be mediated through the endogenous opioid peptide system. In a recent study, infusions of the opioid antagonist naloxone were shown to reduce taste preferences for sugar-fat mixtures and to decrease the consumption of sweet and high-fat foods. The effects were more pronounced among women characterized as compulsive 'binge-eaters' than among control subjects. Cravings by obese or bulimic women for chocolate and other sweet, fat-rich desserts may be under opioid control.

Endogenous opioid peptides are involved in the regulation of energy intake both in humans and in rats. Opioid peptides may influence food intake by mediating the pleasure response to foods. It has been proposed that the sensory pleasure response to foods is largely brought about by the release of endogenous opioid peptides in the brain¹. The blockade of opioid receptors by the administration of opioid antagonists (see Glossary) would thus be expected to reduce taste preferences and the pleasure response to foods and, consequently, to diminish the consumption of preferred foods. Indeed, the opioid antagonists naloxone and naltrexone have been found to reduce food consumption in rats and mice²; such effects appear to be most pronounced for the best-tasting foods. Naloxone and naltrexone selectively reduced the consumption of a fat-rich diet by laboratory rats and prevented the development of obesity³; conversely, opioid agonists such as morphine or butorphanol selectively increase the consumption of dietary fat⁴. Some researchers believe that the primary role of the opioid peptide system is to mediate overeating associated with exposure to pleasant-tasting sweet or high-fat foods⁵.

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Food preferences and the opioid peptide system

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Opioid peptides and taste preferences

Early studies on opioids and taste preferences dealt almost exclusively with preferences for sweet taste and the consumption of sweet solutions. Preferences for sweet taste appeared to be under opioid control. Studies on rats showed that opioid antagonists most effectively reduced intakes of preferred sweet liquids such as glucose, sucrose or saccharin solutions². In addition, limited studies on human subjects showed that oral doses of naltrexone reduced the pleasantness ratings of sucrose solutions and diminished the acceptability of food odors⁶.

More recent studies on human taste preferences have focused on the role of fats in determining food acceptability and food consumption. Typical stimuli studied were basically mixtures of sugar and fat, including milk shakes, cake frostings, cream cheese and ice cream^{7, 8}. Studies on animals have suggested that preferences for dietary fats may also be under opioid control. In one study, the consumption of chocolate milk or chocolate candy by rats caused increased release of the opioid peptide β -endorphin¹⁰. In other studies, infusions of sucrose or fat increased analgesia thresholds (the ability to withstand pain) in infant rats, also suggesting an increase in opioid release in response to the sugar or fat infusion¹¹.

Glossary

Opioid antagonists: Drugs that counteract the effects of opioids, such as naloxone, naltrexone and nalmeferene.

Opioid agonists: Drugs that mimic the effects of opioids, such as morphine and butorphanol.

The recent study by Drewnowski *et al.*⁹ was the first to examine the effects of opioid blockade on human taste preferences for and consumption of mixtures of sugar and fat. Female subjects receiving intravenous naloxone infusions tasted 20 sweetened dairy products with different sugar and fat contents, and rated the 'sweetness' and 'pleasantness' of each sample. Naloxone had no effect on the perception of sweetness intensity. However, 'pleasantness' ratings for all the products were reduced relative to the ratings of subjects given a control infusion of saline, suggesting that opioid blockade does reduce the sensory pleasure response to both sweet and high-fat foods.

Opioid peptides and food consumption

Studies on human subjects have previously shown that opioid blockade leads to a reduction in food intake. In clinical studies, naloxone reduced meal consumption by normal-weight and obese subjects, and diminished the amount of food consumed during 'binges' by female subjects with bulimia¹². Other studies have demonstrated that the opioid antagonists naltrexone and nalmefene reduced energy intakes during a lunch-time meal^{13,14}. Conversely, butorphanol injections led to an increase in the consumption of sandwiches, as measured in the laboratory over a six-hour period¹⁵. The effects of naloxone on specific foods were not systematically measured; however, one study reported that nalmefene selectively reduced the lunch-time consumption of the subjects' most preferred foods, regardless of nutrient composition¹¹.

Sweet desserts rich in both sugar and fat are among the most palatable foods in the Western diet. Such highly preferred foods are frequently the object of food cravings

and feature prominently in reports of eating binges and food 'addictions'; chocolate, in particular, is the most common object of food cravings by women¹⁶. Consequently, the most pronounced effects of opioid peptides on food intake might be expected to be obtained for foods rich in sugar and fat, and especially for foods containing chocolate; accordingly, it might be expected that opioid blockade would selectively reduce the reward value of highly palatable foods and, thus, selectively diminish their consumption.

A recent study⁹ tested the effects of naloxone infusions on the consumption of 16 common snack foods, divided into four categories according to their sugar and fat contents. As shown in Table 1, pronounced effects of naloxone were observed for the foods rich in fat, sugar, or both. On the other hand, in contrast to previous results¹¹, there was no significant correlation between the magnitude of the effects of naloxone and preference ratings for the different foods. Intakes of some of the most highly rated foods (e.g. popcorn) were actually increased by naloxone. Other studies have also suggested that opioid blockade increases the intake of bland carbohydrate-rich foods¹³. The effects of naloxone on food intake were not mediated by changes in hunger ratings, in contrast to the findings of other studies¹⁴ in which hunger ratings were affected by naloxone.

All four foods in the high-sugar, high-fat category happened to contain chocolate. As noted above, chocolate is probably the most common object of uncontrollable food cravings and food 'addictions' among women; furthermore, recent studies have specifically linked cravings for chocolate with the premenstrual syndrome¹⁶. If chocolate consumption leads to endogenous opioid peptide release in humans, as it does in rats¹⁰, then chocolate might be expected to act as a natural analgesic. The possibility that chocolate can reduce pain thresholds in humans is currently under investigation in our laboratory.

Table 1. Snack food intakes of 26 naloxone-treated subjects as a percentage of the intakes of the same subjects given a saline placebo*

Snack food category	Snack food	Relative intake (%)
Low-sugar, low-fat	Popcorn	136
	'Saltines' (crackers)	120
	Bread sticks	85
	Pretzels	74
Low-sugar, high-fat	'Fritos' corn chips	110
	Cream cheese plus 'Saltines'	84
	Potato chips (crisps)	65
	Shortbread	26
High-sugar, low-fat	Jelly beans	85
	Marshmallows	69
	'Jello' gelatin dessert	67
	Jelly (jam) plus 'Saltines'	23
High-sugar, high-fat	Chocolate chip cookies	78
	'Snickers' chocolate bar	54
	'M&M' chocolate candies	41
	'Oreo' chocolate cookies	10

*Taken from Ref. 9

Opioid peptides in obesity and eating disorders

Cravings for chocolate candy and ice cream have been frequently reported among obese and dieting women, and eating binges involving chocolate and ice cream are characteristic of compulsive eating behavior in subjects with bulimia nervosa. Both obese and bulimic women have been shown to have abnormal opioid peptide levels. It may be that the opioid peptide system plays a major role in mediating binge eating episodes among susceptible obese and bulimic individuals. Accordingly, maximal effects of opioid blockade on food consumption are likely to be obtained among subjects showing a pattern of compulsive binge eating.

The recent study of Drewnowski *et al.*⁹ examined the effects of naloxone infusion on food consumption in 14 women who were binge eaters and in 12 normal-weight female controls. Eight of the binge eaters were obese. Caloric intakes in binge eaters were significantly reduced in subjects given naloxone, relative to control subjects given saline. This reduction in food intake was not specific to any particular macronutrient: intakes of

carbohydrate, protein, and fat were all significantly reduced. However, the overall reduction in intake was largely due to the reduced intake of sweet, high-fat foods: the intake of chocolate and cookies was reduced the most.

Abnormalities in the endogenous opioid peptide system may be linked to heightened sensory preferences for sugar-fat mixtures and compulsive overeating of sweet, high-fat foods. Obvious parallels have been drawn between binge eating and drug addiction, since both behavioral syndromes involve intense cravings and loss of control. It may be that the same physiological mechanisms are involved in mediating food cravings and opiate reward. Both clinical observations and anecdotal reports indicate that sweet cravings tend to be associated with opiate addiction, while opiate withdrawal is sometimes alleviated by sweets¹⁷. The recent studies described above suggest that food cravings in obesity and eating disorders may be mediated by the endogenous opioid peptide system, which may explain the key sensory roles of dietary sugars and fat.

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Book Reviews

As the editors state in their introduction:

'Numerous textbooks treat various aspects of food chemistry and engineering, yet little information is available on the process of industrial food research and development. Currently, no textbooks of academic courses cover the broad area of product development. This void keeps even the most qualified person from reacting an informed decision about a career in this field.'

Attempting to fill this 'void', this book provides an interesting overview of the interface between food product development and the marketplace. It is divided into 19 chapters, dealing with subjects ranging from market perspectives, consumer research, R&D, engineering, safety and logistics to quality assurance and nutritional aspects. The last four chapters are mainly dedicated to peripheral issues: university-industry synergy, the protection of intellectual property, and 'Europe 1992'. More futuristic chapters on 'Local issues in food science and engineering' and 'Strategies for global product development' touch on many interesting newer technologies such as

Food Product Development: From Concept to the Marketplace

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supercritical fluid extraction, irradiation, membrane processes and biotechnology.

The chapter by Ernst Graf and Israel Sam Saguy on the 'R&D process' is an interesting and fairly complete survey of R&D activities in the food business - from the screening of ideas, through feasibility studies and product development, to commercialization and, eventually, maintenance. However, it does not present a balanced view of the state of R&D activity in the food industry. It is true that the food industry spends a lower percentage of its sales income on R&D than drug manufacturers do - but exciting and creative new research is still being carried out!

The book highlights some of the activities and skill requirements that are unique to an industrial food research career, as well as touching on many

different aspects of food product development, to show how the predominantly market-driven industry can deal with rapid changes by adapting existing products and technologies.

Some chapters are rather superficial (rhus, although the book fulfils its purpose as stated in the introduction, its coverage cannot be regarded as exhaustive, as would be expected from a textbook. It does provide a very general overview of the areas that would be of interest to those who do not know much about R&D in the food industry, but need to get involved.

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