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Flavor preference conditioning as a function of fat source

Karen Ackroff *, François Lucas, Anthony Sclafani

Department of Psychology, Brooklyn College and the Graduate School, The City University of New York, Brooklyn, NY 11210-2889 United States

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Abstract

Rats learn to prefer foods based, in part, on postingestive nutrient actions. This study compared the effectiveness of intragastric (IG) infusions of fat emulsions which varied in their fatty acid composition (chain length and saturation) to condition preferences for flavored saccharin solutions. In Experiment 1, food-restricted rats were trained (30 min/day) with one flavor (CS+CO) paired with IG corn oil (CO) and a second flavor (CS+MCT) paired with IG medium chain triglyceride (MCT); the fats were prepared as isocaloric emulsions. A third flavor (CS−) was paired with IG water. The rats subsequently showed a strong preference for the CS+CO (84%) and a weaker preference for the CS+MCT (65%) relative to the CS−. In a direct choice test, the CS+CO was preferred to the CS+MCT by 75%. In Experiment 2, new rats trained with flavors paired with IG corn oil and beef tallow (BT) infusions learned to prefer both the CS+CO (89%) and the CS+BT (82%) relative to the CS−, and preferred the CS+CO to the CS+BT by 67%. The same rats were trained with three new flavors paired with IG infusions of corn oil, vegetable shortening (VS), and water. The rats strongly preferred both the CS+CO (91%) and CS+VS (86%) over the CS−, and they preferred the CS+CO to the CS+VS by 64%. In Experiment 3, new rats trained with corn oil and safflower oil (SO) paired flavors preferred both the CS+CO and CS+SO to the CS−, and equally preferred the CS+CO and CS+SO in two-bottle tests. The rats were also given one-and two-bottle tests with the various fat emulsions and their preference profile was consistent with their conditioned preferences for the flavored saccharin solutions. These findings demonstrate that many different fat sources can condition flavor preferences. Fats with high polyunsaturated content and/or lower saturated fat content are the most reinforcing.

Keywords: Flavor preferences; Gastric infusions; Fat

1. Introduction

The intake of fat-rich foods is associated with the development of obesity. The palatable flavor, high energy density and metabolic consequences of high-fat foods are all thought to contribute to overeating and obesity (e.g., [9,11,50,63]). Interest in understanding the controls of fat intake has largely focused on the satiating effects (or lack thereof) of dietary fat. The attractive nature of high-fat foods is widely acknowledged, but this basis for intake promotion by fats has not been fully explored.

Attraction to fatty foods has both oral and postoral aspects. Although the flavor of dietary fat has long been considered to be due to its odor and texture [25,43,44], recent work suggests that rodents can taste fatty acids in the oral cavity and thus gustatory stimulation may contribute to palatability [13,14,16,18,24,62]. Rats are also attracted to nonnutritive oils but can distinguish them from nutritive oils in both real-feeding [1] and sham-feeding tests [39]. The brief duration of these tests and the use of dilute emulsions suggest that postingestive effects are not required for fat detection.

The attractive qualities of foods are modulated by the postingestive actions of nutrients including fat [55]. This is assumed to occur through a Pavlovian conditioning process in which postoral unconditioned stimuli (US) generated by the nutrient reinforce a positive evaluation of the food's accompanying flavor (the conditioned stimulus, CS). In the laboratory this flavor conditioning process can be studied by pairing the intake of an arbitrary flavor (the CS+) with the

* Corresponding author. Tel: +1 718 951 5606; fax: +1 718 951 4824.
E-mail address: kackroff@gc.cuny.edu (K. Ackroff).

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intragastric (IG) infusion of a nutrient; intake of an alternate flavor (the CS−) is paired with an IG water infusion. A conditioned change in the evaluation of the CS+ flavor is then demonstrated by increased acceptance of and/or preference for the CS+ flavor compared to the CS− in one- and two-bottle tests. Using this methodology, several studies have documented the preference conditioning effects of IG fat infusions [29–31,34,42,45,54,59–61]. In long-term sessions, IG infusions of fat or a high-fat food sometimes [4,32], but not always [29,45] elevates the absolute intake (*acceptance*) of the associated CS+ flavor demonstrating the ability of the postoral actions of fat to promote overeating even when a fatty flavor is not present.

Studies of fat-based flavor conditioning have used corn oil, a source of long-chain triglycerides (LCT), as the fat source. Studies of fat-associated hyperphagia and satiation, have compared the effects of different fat sources. Although little difference among fats has been observed in some experiments [5,20,21,23,49] others indicate differences in the satiating action of a function of the type of fat used [12,36,37,40].

The purpose of the present study was to compare postoral flavor conditioning by corn oil with that of other fat sources differing in fatty acid composition. Because these chemical characteristics affect many of the physiological effects of lipids, they could theoretically influence the reinforcing potency of dietary fats. We are sensitive to this possibility because parallel work with carbohydrate-conditioned flavor preferences has shown that carbohydrate sources differ in their reinforcing actions. For example, rats acquire strong preferences for flavors paired with IG infusions of glucose, are indifferent of a fructose-paired flavor, and avoid a flavor that was paired with galactose infusions [52]. Studies that compared the effectiveness of corn oil emulsions and isocaloric carbohydrate solutions in reinforcing flavor acceptance [relative to starch, 45] or preference (vs. glucose polymer, [34,42,61]) found that the carbohydrates were more potent. This may reflect, in part, the slower processing and absorption of fats than of carbohydrates. Together, these findings suggest that fat sources may also differ in reinforcing potency.

In the present study, to maximize the differences in the postoral stimuli generated by the various fat sources studied, the rats were food restricted and trained in short daily sessions. This insured that the infused fat did not mix with food in the upper gastrointestinal tract. Previous work has demonstrated that rats will acquire flavor preferences based on IG fat infusions when food restricted and when nonrestricted [29,45,65]. We began with MCT oil, which is processed more rapidly than LCT sources and therefore might condition a stronger preference than corn oil. Next we looked at two sources, beef tallow and vegetable shortening, that overlapped with corn oil in fatty acid types but differed in fatty acid proportions and degree of saturation. Finally, testing a notion about specificity of fatty acid effects, we tested safflower oil, which has a higher linoleic acid content than corn oil. All three experiments used a training procedure adopted from other comparisons among nutrients [4,6,34,35,41]. Rats were trained with one CS+ flavor paired with corn oil infusion, another CS+ flavor paired with another fat source, and a CS− paired with water infusion. Reinforcing efficacy was assessed both by CS+ vs. CS− comparisons, showing the potency of each fat source alone, and by comparison between the two fat-paired flavors, which revealed their relative strengths. In addition to comparing the postingestive reinforcing actions of the various fat sources, one-and two-bottle intake tests were conducted to determine the relative acceptance and preference of the fat emulsions when they were orally consumed.

2. Experiment 1

Experiment 1 compared corn oil with a distinctively different fat, a medium-chain triglyceride preparation. This consisted entirely of saturated fatty acids with chain lengths of 6, 8 and 10 carbons. In contrast corn oil is composed of long-chain triglycerides (14–18 carbons), mostly unsaturated fatty acids (Table 1). Characteristics of MCT, relative to LCT, include faster gastric emptying and hydrolysis, faster and more direct absorption accomplished largely via the portal vein (LCT are transported via lymphatics), faster and more extensive oxidation, and the potential for greater satiating effects with shorter delay [7]. Some of the outcomes of these differences, such as more rapid availability of MCT energy, could result in greater effectiveness of MCT oil than corn oil as a postoral reinforcer of flavor preferences. One result consistent with this idea is the similarity of responses to flavors paired with various carbohydrates and with MCT oil, compared to corn oil-paired flavors [64]. In that study, the rats were reluctant to drink the MCT oil emulsion, presumably due to its flavor; the present study removes the influence of MCT flavor to focus on its postingestive reinforcing potency.

2.1. Methods

2.1.1. Subjects

Adult female Sprague–Dawley rats ($n=17$) were born in the laboratory from stock obtained from Charles River Laboratories (Wilmington, MA). The animals were individually housed in stainless steel hanging cages with ad lib access to water in rooms maintained on a 12:12 h light:dark cycle (lights on 0800 h) at 21 degrees C. The maintenance diet was powdered chow (No. 5001, PMI Nutrition International, Brentwood, MO; 3.3 kcal/g). Body weights ranged from 240–325 g (mean 282 g) at the beginning of the experiment.

2.1.2. Surgery

The rats were fitted with an IG catheter according to a technique adapted from Davis and Campbell [8]. Briefly, a