

## REVIEW/ DERLEME

**SENSORY SPECIFIC SATIETY : HOW SPECIFIC IS THE SATIETY?***DUYUSAL SPESİFİK TOKLUK: TOKLUK NE KADAR SPESİFİKTİR?*Fatmanur DİLBAZ<sup>1\*</sup>, Sine YILMAZ<sup>2</sup>

Received/Geliş tarihi: 01.08.2025 • Accepted/Kabul tarihi: 18.09.2025

**ABSTRACT**

Sensory Specific Satiety (SSS) is defined as the decrease in liking for a food after its consumption, necessitating the examination of interactions between foods and changes in liking post-consumption. Various studies indicate that SSS stems from the sensory properties of the consumed food and that these liking changes occur rapidly during consumption. While diversity among foods can increase consumption, a monotonous diet may decrease long-term liking and influence food choices. Moreover, the presentation of various foods and individuals' ability to choose their own foods can enhance consumption desire and overall satisfaction. However, the effects of food monotony on body weight remain unclear, necessitating further research. In conclusion, the relationship between SSS and food variety is a significant factor influencing food intake and choice, requiring further exploration of its mechanisms.

**Keywords:** Sensory-specific satiety, Food variety, Changes in liking

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## INTRODUCTION

Sensory Specific Satiety (SSS) refers to the decline in pleasure experienced from the sensory attributes of a particular food as it is being consumed (1). The concept of SSS was first formally introduced by Rolls and colleagues, who demonstrated that the pleasantness of a food decreases rapidly during consumption while other uneaten foods remain relatively unaffected (2). In humans, SSS is typically assessed by analyzing changes in perceived pleasantness of taste, smell, texture, or appearance before and after eating. These hedonic shifts are often compared with responses to foods that are not consumed. Subsequent studies confirmed that the reduction in sensory pleasantness is more pronounced for the eaten food compared with uneaten alternatives (3). Additional experimental evidence supported this finding (4), and more recent work further validated its role in appetite regulation (5).

The distinction between SSS and allesthesia has been a source of confusion in the literature (6). Allesthesia involves sensory changes driven by alterations in internal states or physiological needs for specific substances. Hedonic changes associated with allesthesia occur gradually, typically over an hour after consumption, and tend to be nonspecific—for instance, a generalized reduction in the pleasantness of all food odors following a sugar intake. These changes are believed to originate in the duodenum (7).

SSS has been extensively investigated through a series of experiments involving normal weight individuals who were not actively dieting (2). In these experiments, subjects were presented with small portions of different foods and asked to rate their pleasantness with regard to sensory properties. Participants were then offered one of these foods as a meal and allowed to eat freely until satisfied. Immediately following the meal and at subsequent intervals, they were asked to reassess the foods they had initially evaluated. Within two minutes following the meal, the taste, smell, texture, and appearance of the consumed food exhibited a markedly greater decline in pleasantness compared to the uneaten foods. These changes were monitored for an hour after



the meal, and it was observed that pleasure decreased the most in the first two minutes and gradually recovered over the next hour. The occurrence of these changes before most of the food is absorbed from the digestive system indicates that the sensory properties of the food primarily drive the hedonic response. If physiological benefits were the dominant factor, the decline in pleasure would persist beyond the two-minute mark. However, the rapid decrease in pleasure indicates that sensory cues are the main factor in this response (3). This has been demonstrated in further experimental evidence (4) and confirmed in more recent studies (5).

In another study, 50 participants were divided into control and experimental groups. The experimental group consumed chocolate, vanilla ice cream, salty cookies, and apples, while the control group was not given any food. Results showed that appetite for the consumed food decreased, but the desire for different foods increased in the experimental group. In contrast, the control group's general appetite was assessed without offering a specific food. These findings suggest that sensory variety may be effective in regulating appetite and potentially in combating obesity (8).

Another approach to understanding the role of internal states in altering pleasantness responses is to compare the effects of nutritious and non-nutritious foods. Wooley and colleagues (9) found that a noncaloric sweetener solution containing cyclamate was as effective as glucose in diminishing the pleasantness of a 20% sucrose solution. However, the relevance of these findings to typical eating behaviors remains uncertain. A similar pattern was observed in studies of caloric compensation in children (10), in research exploring thirst and hedonic regulation (11), in recent work on olfactory and gustatory stimuli (12), and in investigations of peripheral appetite mechanisms (13). Collectively, these studies strengthen the argument that SSS is primarily driven by sensory properties rather than by energy intake.



## **Saturation and Satiety**

Satiety refers to the sensation of fullness that lasts between meals, helping to regulate the timing of the next meal, whereas satiation describes the feeling of fullness experienced during a meal, signaling the point at which eating should stop (14). Satiety and satiation are regulated by a series of physiological mechanisms that begin after the consumption of a food or drink and continue with the digestion and absorption of nutrients reaching the stomach (15). Signals related to energy intake are transmitted to specific regions in the brain in response to stomach expansion, in addition to sensory and cognitive perceptions of the consumed food or drink. These regions play a role in regulating energy intake (16). The brain integrates these signals and, as a result, the feeling of satiety is stimulated, reducing the individual's desire to consume more food. Once nutrients reach the intestines and are absorbed, a series of hormonal signals are released that are transmitted to the brain to trigger a feeling of fullness. In addition to these short-term signals, changes in the levels of hormones such as leptin and insulin, which indicate the body's fat stores, also affect the feeling of satiety and ensure long term energy balance (17).

### **How Specific Is Satiety?**

The largest postprandial palatability changes are not limited to the consumed food; some unconsumed foods also experience palatability reductions. These interactions may arise due to similarities in the sensory characteristics of the foods, their cognitive classification as the same type, or possibly because they share the same macronutrient composition (18). For example, consuming a sweet food decreases the pleasantness of other sweet foods, whereas salty or nonsweet options remain unaffected. Similarly, consuming salty foods reduces the pleasantness of other salty items but does not impact sweet foods (7). These effects are likely influenced by similarities in taste or flavor, although they may not arise if the foods differ substantially in



other sensory attributes (19). Such interactions may also be shaped by beliefs about similarities between foods, suggesting that hedonic responses can be cognitively mediated (20).

In a study conducted with 12 adults, participants were presented with chicken and banana as test foods, and their hedonic responses were measured after consumption. Results indicated that changes in odor intensity were less pronounced, while decreases in odor pleasantness occurred independently of intensity changes. This experiment provided important insights into how SSS is associated with both odor and taste stimuli and how these sensory cues contribute to satiety (21). These findings also suggest a novel approach to meal planning: by identifying foods that exhibit minimal sensory interaction, it may be possible to sustain a high level of palatability throughout the entire meal (6).

The Western meal pattern inherently highlights the diverse sensory qualities of food. A meal beginning with a soup or salad, followed by a main course of meat and vegetables, and concluding with a dessert that emphasizes contrasts in color and texture, can effectively reduce appetite, particularly if the sense of fullness experienced during the meal is strategically managed (6,7).

### **Food Specific Satiety**

Interactions between foods can arise not only due to similarities in their sensory characteristics but also because of comparable macronutrient content. Such interactions would be expected if the body's physiological need for specific nutrients played a significant role in hedonic responses (18). However, research on the specificity of satiety related to macronutrient composition remains limited. For instance, consumption of hazelnut butter has little effect on the perceived pleasantness of other food odors and tastes, while protein-containing foods show moderate influences (21), and carbohydrate-rich foods produce the most pronounced changes in hedonic ratings (22,23).



To further examine the role of macronutrients, participants were provided with isocaloric portions of foods that were high in one macronutrient but low in others (24). To test possible cross-interactions, each food was paired with another item sharing similar nutrient content but differing in sensory characteristics. As expected, the most significant decrease in pleasantness was observed for the food actually consumed. In contrast, uneaten foods, whether nutritionally similar or different, exhibited minimal hedonic changes. Moreover, when a varied meal was offered two hours later, the nutrient composition of the preload had no impact on subsequent food choices.

These findings suggest that hedonic responses are not primarily determined by macronutrient content. Instead, they indicate that SSS is mainly driven by the sensory properties of foods, rather than by physiological needs for specific nutrients (6).

### **Diversity and Nutrient Consumption**

If satiety is tied to specific properties of foods, providing a variety of options during a meal is likely to result in increased overall food consumption. Variety in a meal can boost energy intake, as changing even a single sensory property can encourage more intake. The larger the differences between the foods offered, the more significant the increase in consumption (6). Sorensen and colleagues further confirmed that sensory perception of different foods strongly affects appetite regulation (25). In addition, Raynor and Epstein highlighted that dietary variety has the potential to undermine energy balance by increasing caloric intake (26).

Differences in the palatability of foods can also increase consumption. Presenting cream cheese sandwiches sequentially with varying flavors such as salt, curry, and a lemon–saccharin combination led to a 15% increase in consumption compared to when only the most preferred flavor was offered. It was important that these sandwiches had different flavors at baseline because no similar increase was seen with three different yogurt or three different chocolate



flavors, which were otherwise identical. This effect was attributed to the fact that all the foods were sweet and belonged to the same category (26).

In one controlled experiment, 40 adults were randomly assigned to two groups: 20 participants in the control group and 20 in the experimental group. The control group continuously consumed a single type of food, whereas the experimental group was consecutively presented with different flavored items such as strawberry yogurt, banana, potato chips, and milk chocolate. Hedonic ratings and feelings of fullness were measured after each item. The results indicated that exposure to different flavors significantly increased the desire to eat and led to higher overall intake in the experimental group compared to controls (27).

Differences in the shape of foods may also increase consumption by affecting both appearance and mouthfeel. When three different pasta shapes were presented in succession, consumption increased by 14% compared with the most popular shape presented in succession (28). When only the flavor or shape of the food was changed, consumption increased by about 15% over three consecutive trials. The increase was greater when more of the food characteristics were different. When four sandwiches with very different fillings were presented in succession, consumption was about a third greater than when the same sandwich was consumed continuously (6). The cream cheese sandwiches differed in attributes such as appearance, texture, smell, flavor, and nutritional composition, but they still fell within the same category of sandwiches. In contrast, serving four distinctly different foods in successive courses resulted in an even greater increase in consumption. When a four-course meal consisting of sausage, bread and butter, chocolate fudge, and banana was served, consumption increased by 60% compared to the average intake when only one food was offered (4).

In summary, the more distinct the foods served, the greater the overall consumption. To encourage higher food intake, it is beneficial to offer a variety of foods with contrasting sensory and other properties. On the other hand, if the aim is to limit consumption, offering foods that



are more similar in sensory attributes can help reduce overall intake (18). Several studies have shown that Sensory Specific Satiety (SSS) increases consumption due to variety. Rolls and colleagues provided early evidence that SSS plays a central role in regulating intake (4). Later experiments confirmed these findings and highlighted the role of sensory changes in satiety (5). More recent studies also emphasized that SSS directly contributes to the effects of dietary variety on food consumption (6).

When different foods are consumed at successive meals, the taste pleasantness of the uneaten food decreases only slightly, even after two or three meals have been eaten (8). Specific changes in the perceived taste of a food influence subsequent consumption. For instance, if a food eaten during a previous meal becomes less pleasant due to SSS, it tends to be consumed in smaller quantities at the next meal. This decrease in pleasure for that particular food helps regulate intake by reducing the desire to eat the same food again soon (5). Conversely, foods that were not eaten previously may be consumed in greater quantities, as they do not trigger the same hedonic response (6).

The relationship between changes in the pleasantness of food and the amount consumed is indeed significant. These findings support the idea that one key mechanism for regulating food intake is the reduction in the pleasantness of a food as it is consumed. This phenomenon, known as SSS, serves as a natural feedback loop, signaling to the body when enough of a particular food has been consumed. As the food becomes less pleasant, the desire to continue eating it diminishes, helping to regulate overall intake and prevent overeating of any one food (4).

It is important to emphasize that SSS interacts with other environmental and physiological factors that influence food intake and choice. During normal eating, food pleasantness responses may be an important factor in food intake in some cases, but have little influence in other cases (18).



## **The Impact of Dietary Monotony**

So far, this manuscript has primarily examined the pleasurable reactions to food during and in the hours after a meal. Now, we turn to changes in food preferences that can emerge over more extended periods, beyond daily consumption. Over time, people may grow bored with specific foods, leading them to reduce or cease consumption. For example, a study on the effects of uniform army rations indicates that repeated exposure to the same foods can result in a lasting decline in their likability (29,30).

Foods like meat, seafood, and those high in fat or typically served as main meals are strongly desired after a prolonged absence but elicit little desire when consumed recently. In contrast, foods that are not the main focus of a meal and are lower in fat or protein, such as bread, salads, potatoes, and certain desserts, show a more consistent preference, retaining their appeal even when consumed daily (31).

A study highlighted the significance of understanding how monotony affects food intake. In research conducted with Ethiopian refugees, participants who had consumed the same three foods for approximately six months reported finding these foods less pleasant compared to new options. However, refugees who had consumed the familiar diet for only two days rated its taste as equally pleasant as the new foods. The monotonous nature of the diet led them to replace the basic foods with less nutritious options and to prepare the monotonous foods inadequately. This effect can be overcome by adding spices to vary the taste of the foods, just as people do when they are fed a single food (32).

Decreases in pleasantness extend beyond a meal, affecting the overall acceptability of some foods. However, this is not the same phenomenon as SSS. Sensory Specific Satiety occurs quickly after a meal and typically involves a decrease in the pleasantness of the consumed food's sensory attributes, such as taste, smell, and texture, while other foods remain unaffected (19). The food industry often refers to long-term decreases in food acceptability as "weariness."



Weariness is believed to be partly caused by cognitive satiety (33). This occurs when a person becomes aware of the overconsumption of a particular food and develops a desire for variety. Overeating or feeling compelled to eat the same food repeatedly can lead to cognitive satiety, which reduces the appeal of that food (18). One piece of evidence supporting the cognitive hypothesis is a study that showed how allowing individuals to choose the foods they would include in a repeated diet helped reduce dissatisfaction with the diet. This self-selection process seemed to mitigate the negative effects of monotony and helped maintain the appeal of the foods over time (34). Overall satisfaction with a 3-day self-planned menu cycle was found to be comparable to a 6-day cycle of a pre-selected menu. This suggests that the ability to choose one's own foods can enhance satisfaction, even when the variety of the menu is limited to a shorter period. Forcing people to eat foods they did not choose may decrease their preference for those foods. This finding aligns with a study in young children, which showed that foods that were force-fed in exchange for rewards led to a reduced preference for those foods (35).

### **Variety, Monotony and Body Weight**

Sustaining body weight might partially depend on the availability of a diverse and enjoyable diet. A study examining the impact of a monotonous liquid diet found that both obese and normal-weight participants voluntarily decreased their intake, resulting in weight loss. This highlights how dietary monotony may inherently reduce consumption and support weight control (36). Evidence suggests that freely available, varied, and palatable diets can contribute to excessive weight gain. The wide range of sensory experiences in such diets can reduce Sensory Specific Satiety (SSS), encouraging overeating and increasing overall caloric intake (37). Studies on caloric regulation among hospitalized obese and normal-weight individuals have shown that providing a plentiful and varied diet can result in overeating and significant weight gain within just 3 to 6 days. The increased variety likely prolongs palatability and reduces SSS, driving higher caloric intake (38).



In another study, participants in the experimental group were given a variety of foods, including chocolate cake, yogurt, mixed nuts, and grapes. Participants in the control group were assessed for general appetite without being presented with a specific food. This group was not exposed to any SSS stimuli. Experimental evidence suggests that the onset of SSS for a particular food is associated with the activation of the brain's reward systems (39). Neuroimaging studies have shown that as a food is consumed, reward-related brain regions such as the orbitofrontal cortex decrease their response to that specific food, while the appeal of uneaten alternatives is maintained (40,41). In experimental studies, participants exposed to this mechanism experienced quicker satiation with specific foods, while those in the control group maintained more consistent overall appetite levels, suggesting a dynamic interaction between sensory exposure and the brain's reward pathways (42).

A study on rats examined how variety influences food intake using foods with comparable energy densities that were similarly consumed in preliminary trials, suggesting equivalent taste appeal. The rats were divided into groups and provided either laboratory chow alone, chow with one palatable food, chow with three palatable foods (cookies, crackers, chocolate) presented sequentially (rotated every 12 hours), or all three palatable foods offered simultaneously. Rats given any palatable food ate more than those fed chow alone. Notably, rats offered a simultaneous variety of palatable foods consumed the most and, after seven weeks, showed significantly greater weight gain and body fat accumulation compared to the groups offered the same foods sequentially (43).

The influence of variety on food consumption extends beyond individual meals and may contribute to obesity. In affluent societies, the constant availability of diverse food options stimulates appetite, heightening the risk of overeating. Without conscious efforts to limit intake, the heightened consumption driven by variety can contribute significantly to weight gain and obesity (44,45).



### **Sensory Specific Satiety Mechanisms**

During SSS, the perception of certain foods by the sense organs leads to various responses in the autonomic nervous system (ANS). These responses include changes in heart rate, adjustment of blood pressure, and regulation of gastrointestinal functions (46). ANS contributes to the formation of SSS by affecting the release of appetite-regulating hormones (leptin, ghrelin) and increases the interest in other foods by reducing the attractiveness of certain foods. In addition, ANS interacts with reward centers in the brain and affects dopamine release in food preferences, helping to reduce appetite (47).

In a study by Mower et al., research on the effects of food consumption on odor stimuli revealed a decline in the perceived pleasantness of the odors, though the intensity of the stimuli remained consistent (48). Electrophysiological studies in monkeys provide insights into the mechanisms of SSS. In these studies, single-cell electrical activity was recorded as monkeys consumed specific foods to satiety. Interestingly, in brain regions associated with the sensory analysis of taste stimuli, including the nucleus tractus solitarius and the opercular cortex, as well as areas involved in visual processing such as the inferior visual temporal cortex and the amygdala, satiety did not alter the neural responses of these cells (49). This finding contrasts sharply with the behavior of neurons in the lateral hypothalamus, a brain region essential for regulating motivational states and reward during consumption. In hungry monkeys, neurons in this area show heightened activity in response to the sight or taste of food. However, as the food is consumed, the activity of these neurons decreases, leading to a reduced willingness to continue eating that specific food. When a new food is presented, these neurons re-engage, and the monkey readily consumes the novel option (50). These observations suggest that SSS is not linked to changes in sensory processing but is instead governed by brain regions that evaluate the motivational and reward value of food. To further understand the neural basis of SSS, Rolls and colleagues mapped the pathway of taste processing from the primary taste cortex in the



opercular region to the secondary gustatory area, the caudolateral orbitofrontal cortex. This secondary area is crucial for assessing the reward value of food and maintains direct connections to the lateral hypothalamus, which governs motivation and reward-related behaviors (51).

Research has shown that SSS is associated with the activity of neurons in the caudolateral orbitofrontal cortex. It is suggested that as food is consumed, the responsiveness of neurons in this region changes, and these alterations are believed to form the neurophysiological basis of SSS (52). Cognitions likely play a role in SSS. Through experience and learning, individuals come to understand how much food they can consume during a meal, and when this limit is surpassed, the food may become less enjoyable or unpalatable (53). This learning process involves understanding the caloric value of foods and determining appropriate portion sizes, all of which are based on the sensory properties of the foods. Since our cognitive perceptions of food are closely tied to these sensory attributes, it can be challenging to distinguish between SSS and cognitive satiety as separate phenomena (54).

## **CONCLUSION AND RECOMMENDATIONS**

Sensory specific satiety is a complex mechanism that plays a crucial role in regulating eating behavior and energy intake. Research has demonstrated that the level of pleasure associated with a particular food decreases after its consumption, but this decline in pleasure is not observed when different foods are consumed. This phenomenon encourages individuals to eat a variety of foods, thereby promoting the consumption of a broad range of nutrients and contributing to the maintenance of a balanced diet. When the mechanisms of sensory specific satiety are examined, it is seen that both psychological and physiological factors play a role. While taste, smell, textural properties and visual stimuli affect the levels of pleasure of foods, hormonal signals and brain structures also modulate this process. Studies have emphasized the



impact of sensory specific satiety on the central nervous system, particularly in regions such as the hypothalamus and orbitofrontal cortex. In practice, the use of sensory specific satiety in controlling eating behavior opens the door to new strategies in the management of nutritional problems such as obesity and overeating. Increasing food variety is important in terms of preventing monotonous nutrition and balancing nutritional intake. In addition, monitoring the levels of food consumption can help individuals manage their eating habits more consciously and healthily. As a result, sensory specific satiety has an important place in nutrition science and eating behavior research. A deeper understanding of sensory specific satiety can contribute to the development of new strategies aimed at promoting healthy eating habits and preventing nutrition-related health issues. Future studies will expand the knowledge in this area by examining the long term effects of Sensory Specific Satiety and its differences between individuals in more detail .

### **Kısaltmalar**

SSS: Sensory Specific Satiety

ANS: Autonomic Nervous System

**Conflict of interest:** The authors declare that they have no conflict of interest.

**Financial disclosure:** No financial support was received for this research.



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