RESEARCH ARTICLE/ARAŞTIRMA MAKALESİ

INVESTIGATION OF THE EFFECT OF VEGETABLE CRUNCH CONSUMPTION AS A SNACK ON BLOOD GLUCOSE, SUBJECTIVE APPETITE PARAMETERS AND ENERGY INTAKE OF THE NEXT MEAL

ARA ÖĞÜN OLARAK SEBZE KITIRI TÜKETİMİNİN KAN GLİKOZ, SUBJEKTİF İŞTAH PARAMETRELERİ VE BİR SONRAKİ ÖĞÜN ENERJİ ALIMLARI ÜZERİNE ETKİSİNİN İNCELENMESİ

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ABSTRACT

Aim: Obesity is a complex condition with pathophysiological, social and psychological effects on individuals of all ages and socioeconomic groups. When foods with low energy density and high fiber content are consumed, satiety may occur early and the feeling of fullness may last for a relatively long time. Therefore, substituting high-energy foods with low-energy foods such as fruits and vegetables can potentially reduce total energy intake. The aim of this study was to investigate the effect of consuming vegetable crunch as a snack on acute appetite and energy intake at the next meal. **Materials and Method:** This study included 20 adults, 7 males and 13 females, aged between 18-30 years, of normal weight. The individuals included in this study were asked to come to the laboratory for three days (Day 1 - General Assessment Day 2 - Snack meal containing vegetable crunch Day 3 - Snack meal containing apple). Individuals who agreed to participate in the study were given a breakfast meal consisting of half-fat cow's milk (300 mL), feta cheese (60 g), white bread (75 g), a snack containing vegetable crunch (25 g) or apple (160 g), and an ad libitum lunch containing cheddar cheese (60 g), tomato (50 g), and white bread (100 g) on non-consecutive days. **Results:** In this study, postprandial visual analog scale assessments, capillary blood glucose measurements, and ad libitum energy intake at the

next meal were evaluated. No statistically significant difference was found in blood glucose, subjective appetite parameters and ad libitum energy intake data of the individuals according to the midday meal administration. **Conclusion:** The use of snacks plays an important role in weight management and further clinical studies should be conducted to determine different food types that will contribute to this process.

Keywords: Appetite, Snack, Vegetable Crunch, Energy intake

ÖZET

Amaç: Obezite, her yaştan ve sosyoekonomik gruptan bireyi etkileyen patofizyolojik, sosyal ve psikolojik etkileri olan karmaşık bir durumdur. Düşük enerji yoğunluğuna ve yüksek lif içeriğine sahip gıdalar tüketildiğinde, doygunluk hissi erken ortaya çıkabilir ve nispeten uzun süre devam edebilir. Bu nedenle, yüksek enerjili gıdaların meyve ve sebze gibi düşük enerjili gıdalarla değiştirilmesi, toplam enerji alımını potansiyel olarak azaltabilir. Bu çalışmanın amacı, sebze gevreğinin ara öğün olarak tüketilmesinin akut iştah ve bir sonraki öğündeki enerji alımı üzerindeki etkisini araştırmaktır. **Gereç ve Yöntem:** Bu çalışmaya, 18-30 yaşları arasında, normal kilolu 7 erkek ve 13 kadın olmak üzere 20 yetişkin dahil edilmiştir. Çalışmaya dahil edilen bireylerden üç gün boyunca laboratuvara gelmeleri istenmiştir (1. Gün - Genel Değerlendirme, 2. Gün - Sebze gevreği içeren ara öğün, 3. Gün - Elma içeren ara öğün). Çalışmaya katılmayı kabul eden bireylere, ardışık olmayan günlerde, yarım yağlı inek sütü (300 mL), beyaz peynir (60 g), beyaz ekmek (75 g), sebze gevreği (25 g) veya elma (160 g) içeren bir ara öğün ve çedar peyniri (60 g), domates (50 g) ve beyaz ekmek (100 g) içeren serbest tüketimli bir öğle yemeği verildi. **Bulgular:** Bu çalışmada, yemek sonrası görsel analog ölçek değerlendirmeleri, kılcal kan şekeri ölçümleri ve bir sonraki öğünde serbest tüketimli enerji alımı değerlendirildi. Öğle yemeği uygulamasına göre bireylerin kan şekeri, öznel iştah parametreleri ve serbest tüketimli enerji alımı verilerinde istatistiksel olarak anlamlı bir fark bulunmadı. **Sonuç:** Ara öğünlerin kullanımı kilo yönetiminde önemli bir rol oynamaktadır ve bu sürece katkıda bulunacak farklı gıda türlerini belirlemek için daha fazla klinik çalışma yapılmalıdır.

Anahtar kelimeler: İştah, Ara öğün, Sebze gevreği, Enerji alımı

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INTRODUCTION

The global prevalence of overweight and obesity has doubled since 1980, and approximately one-third of the world's population is classified as overweight or obese (1). Obesity is a complex condition affecting individuals of all ages and socioeconomic groups, with pathophysiological, social, and psychological consequences (2). Control of appetite metabolism is important in the development of obesity (3). As appetite increases, individuals' energy intake rises, and with the increase in body fat percentage, obesity is observed. Appetite is a mechanism that affects energy intake and sensations such as hunger (4). Studies show that snack consumption influenced by appetite has significantly increased over the years among young adults aged 19–29 years. As the number of snacks consumed throughout the day increases, daily energy intake rises, leading to a higher prevalence of obesity (5).

Snacks mostly refer to foods consumed between main meals to relieve hunger (6). Fruits have long been described as a "healthy snack." Standard fruit snacks are rich in carbohydrates and are found to be palatable (7). Fruit consumption has a risk-reducing effect on overweight and obesity. It is known that the soluble dietary fibers they contain reduce total energy intake, which may result in weight loss. Dietary fibers lower the glycemic index of foods, providing prolonged satiety (8). Standard vegetable snacks, on the other hand, are not found to be as palatable as fruit. Therefore, vegetable snacks have recently started to be offered in alternative forms using advanced technologies to increase their consumption (7). This technology involves drying processes that do not damage the content of the products. Through drying, crispy vegetable pieces are obtained. Crispy vegetables have become preferred snack options (6). Recent clinical and epidemiological studies have shown that different vegetable products contain phyto-protective compounds that may have beneficial effects on human health (9). To produce crispy vegetable snacks, advanced drying and non-thermal techniques (e.g. pulsed electric fields, high-pressure processing) are increasingly utilized to maintain phytonutrient retention and sensory quality (10).

Fruits and vegetables have low energy density, high water content, and contain significant amounts of soluble dietary fiber. When foods with low energy density and high fiber content are consumed, satiety may occur earlier and fullness may persist for a relatively longer period of time. Therefore, replacing high-energy foods with low-energy foods like fruits and vegetables may potentially reduce total energy intake (8). Given that WHO recommends ≥ 400 g/day of fruits and vegetables to reduce non-communicable disease risk (11), and vegetable-based interventions have consistently been shown to reduce daily energy intake and body

weight (12). In this study, the aim was to investigate the effect of consuming crispy vegetables as a snack on acute appetite and subsequent meal energy intake in young adults.

MATERIAL AND METHOD

Young adults with normal body weight were included in this study. Individuals aged 18–30 years with normal weight, who did not have any chronic diseases or food allergies, were invited to participate via posters and personal communication, and those who were interested were provided with detailed information about the study. Individuals who read the informed consent form and agreed to participate signed the form and were then evaluated by the researchers according to the inclusion and exclusion criteria. Those who met the criteria were included in the study. The inclusion criteria for the study were being between 18–30 years of age and having a normal body weight [Body Mass Index (BMI) = 18,5–25]. The exclusion criteria were cancer, chronic diseases, food allergies, weight gain or loss of more than 5% in the last three months, engaging in regular and high-intensity physical activity, being on a weight-gain or weight-loss diet, and having genetic and/or metabolic diseases. Participants who were included in the study were asked to come to the laboratory where the study would be conducted on three separate days.

Day 1 – General Assessment

Day 2 – Snack intervention containing vegetable crisps

Day 3 – Snack intervention containing fresh apple

Study Protocol

Participants visited the research laboratory on three separate days: one general assessment visit and two test sessions. During the general assessment visit, body weight and height were measured after 8 hours of fasting. There was a minimum interval of 1 day and a maximum of 1 week between the test days. During the interval between test days, participants were asked to maintain their usual dietary habits. They were informed to arrive on the test day after a 12-hour fast, without having taken any medication in the previous 24 hours, and without having engaged in physical activity in the previous 48 hours. The study protocol was approved by the Clinical Research Ethics Committee of University of Health Sciences, Gülhane Training and Research Hospital with decision number 2023/72 on 12.04.2023.

On test days, participants arrived at the laboratory at 08:00 in the morning after fasting since 20:00 the previous evening. Participants were asked to record their dinner from the previous night and to consume the same meal before attending the next test day. At 08:30, baseline hunger and satiety were assessed using a visual analog scale (VAS), and capillary blood glucose measurements were taken. At 09:00, participants were asked to consume the breakfast meal

within 15–20 minutes. At 10:30, participants consumed a snack containing either vegetable crisps or apple. VAS assessments were repeated at 11:00, 11:30, and 12:00; capillary blood glucose measurements were repeated at 10:00, 11:00, and 12:00; and an ad libitum lunch was served at 12:00. During the test session, participants were allowed to sit, read books, walk quietly (also briefly outside the dining room), listen to the radio or watch TV/videos provided that no food-related visuals or descriptions were involved. They were allowed to go to the restroom when needed. Participants were not permitted to sleep during the test session. A total of 200 ml of drinking water was served to participants throughout the test session. All participants received both test meals in a randomized order.

Standard Breakfast Meal

A standard breakfast was provided to the participants by the researchers. The breakfast consisted of semi-skimmed cow's milk (300 mL), bread (75 g), and white cheese (60 g) (Table 1). The cow's milk was served at a temperature below 10°C. The energy and nutrient values of the breakfast meal were calculated using the Nutrition Information Systems (BEBIS 7.2) program.

Table 1. Energy and Nutrient Content of the Standard Breakfast Meal

Foods	Energy (kcal)	CHO (g)	Protein (g)	Fat (g)	Fiber (g)
Semi-skimmed cow's milk (300 mL)	183	14.1	9.9	9.9	-
White cheese (60 g)	173.4	-	13.5	13	-
White bread (75 g)	200.2	44.1	4.5	0.6	3.5
Total	556.6	58.2	27.9	23.5	3.5

Test Snacks

Participants were provided with either vegetable crisps (25 g) or apple (160 g) as the test snack by the researchers. The energy and nutrient values of the test snacks were calculated using the Nutrition Information Systems (BEBIS 7.2) program (Table 2).

Table 2. Energy and Nutrient Content of the Test Snacks

Foods	Amount (g)	Energy (kcal)	CHO (g)	Protein (g)	Fat (g)	Fiber (g)
Vegetable crisps	25	80	15.2	1.9	-	5.6
Apple	160	83	18.3	0.5	0.6	3.2

Analyses

Anthropometric Measurements

Body weight measurements of the participants were taken during the ***general assessment*** visit and on test days while the participants were fasting, wearing shorts, and without shoes or socks. Height was measured during the ***general assessment*** visit using a stadiometer. Body mass index (BMI) was calculated from the participants' weight and height values.

Capillary Blood Glucose Measurement

Participants' fasting and postprandial blood glucose values at the 60., 120., and 180. minutes were measured using capillary blood glucose testing. Blood samples were obtained from the distal tip of the finger (preferably the 3. or 4. finger), applied onto the appropriate strip, and analyzed with a blood glucose meter.

Visual Analog Scales (VAS)

Participants' hunger and satiety states were evaluated using the VAS questionnaire. In this study, the VAS questionnaire assessed hunger, fullness, desire to eat, and prospective food consumption, with the most positive and most negative ratings recorded at protocol-specific intervals during the test sessions. Each question in the questionnaire was represented on a 10 cm horizontal line with anchored endpoints. Participants were instructed to place a vertical mark on the line according to how they felt at that moment. The quantitative value was determined by measuring the distance (in cm) from the left end of the line to the mark. VAS questionnaires were administered before the test snack and at the 120th, 150th, and 180th minutes after the beginning of test snack consumption.

Ad-libitum Lunch (Food Intake)

Three hours after the start of snack consumption, participants were provided with an ad libitum lunch (Table 3). To measure food intake, participants were asked to consume sandwiches containing cheddar cheese until they felt full. The sandwiches were weighed before and after consumption, and the weight of the leftovers was measured to determine participants' energy intake. The same sandwiches were served to participants on both test days, and 20 minutes were allotted for the ad libitum lunch. Additionally, 200 mL of drinking water was provided. The energy and nutrient values of the sandwiches served at lunch were calculated using the Nutrition Information Systems (BEBIS 7.2) program.

Table 3. Energy and nutrient content of the sandwiches served at lunch

Foods	Energy (kcal)	CHO (g)	Protein (g)	Fat (g)
Cheddar cheese (60 g)	255.1	0	11.5	23.5
White bread (100 g)	255.7	52.9	8.1	0.9
Tomato (50 g)	8.7	1.3	0.5	0.1
Total	519.5	54.2	20.1	24.5

Data Analysis

SPSS 20.0 statistical software package was used for the analysis of all data. Descriptive statistics, including mean, range, standard deviation, and standard error, were calculated for each parameter. One-way ANOVA was used to determine differences between groups. Statistical significance was set at $p<0.05$.

Results

A total of 20 metabolically healthy young adults (13 females, 7 males) were included in this study. The mean age of the participants was 21.7±1.2 years, mean body weight was 63.9±11.5 kg, mean height was 167.8±6.9 cm, and mean BMI was 22.7±3.5 kg/m² (Table 4). All participants completed the study protocol.

Table 4. Baseline Characteristics of the Participants

Participants (n = 20)	Mean ± SD
Age (years)	21.7±1.2
Body weight (kg)	63.9±11.5
Height (cm)	167.8±6.9
BMI (kg/m^2)	22.7±3.5

BMI: Body mass index

Blood Glucose Levels

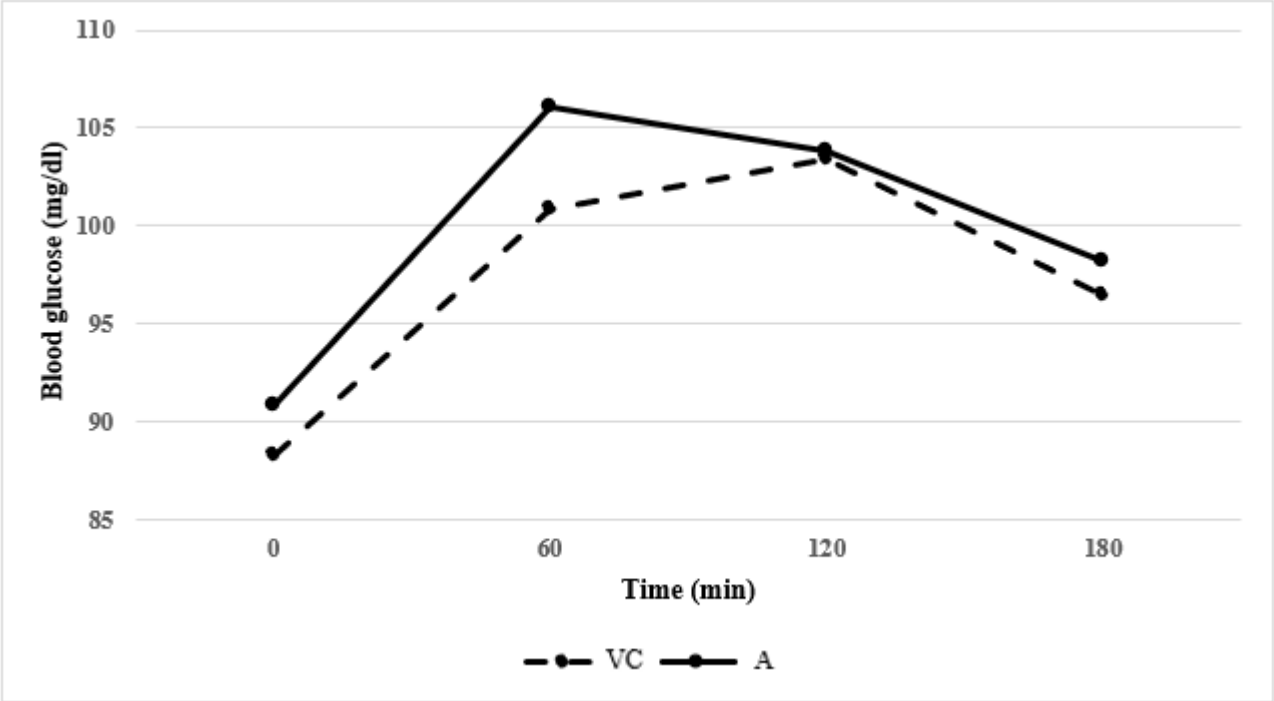
After consumption of the snack containing vegetable crisps, the absolute changes in glucose values of the participants were 12.55±14.77, 15.1±15.9, and 8.2±13.06 mg/dL at the 60., 120., and 180. minutes, respectively. After consumption of the snack containing apple, the absolute changes in glucose values were 15.22±14.024, 12.95±9.561, and 7.3±9.211 mg/dL at the 60., 120., and 180. minutes, respectively. The absolute changes in blood glucose values over time were statistically evaluated between the interventions. No significant differences were found in the increase in blood glucose between 0–60 minutes, 0–120 minutes, and 0–180 minutes across the two interventions ($p=0.063$, $p=0.584$, $p=0.805$, respectively) (Table 5). However, at the 60th

minute, blood glucose levels after apple consumption were found to be higher (not statistically significant) compared to vegetable crisp consumption (Figure 1).

Table 5. Absolute Changes in Blood Glucose levels (mg/dL) After Snack Consumption

Parameter		Postprandial Time		
		0-60. min	**0-120. min**	**0-180. min**
		Mean ± SD	**Mean ± SD**	**Mean ± SD**
Glucose (mg/dL)	**VC**	12.6±14.8	15.1±15.9	8.2±13.1
	A	15.2±14	12.95±9.6	7.3±9.2
	p	0.063	0.584	0.805

VC: Vegetable crisps**, A:** Apple



VC: Vegetable crisps**, A:** Apple

Figure 1. Comparison of Changes in Blood Glucose Levels Over Time Between the Interventions

VAS Assessments

Hunger

After consumption of the snack containing vegetable crisps, the absolute changes in hunger scores over time were 3.605±2.630, 4.595±2.352, and 0.875±2.830 cm at the 120th, 150th, and 180th minutes, respectively. After consumption of the snack containing apple, the absolute

changes in hunger scores were -3.735±2.232, -2.51±1.489, and -0.985±2.496 cm at the 120th, 150th, and 180th minutes, respectively. The absolute changes in hunger scores over time were statistically evaluated between the vegetable crisp and apple groups. No significant differences were found in hunger changes between 0–120 minutes, 0–150 minutes, and 0–180 minutes after consumption of vegetable crisps versus apple (p = 0.999, p=0.596, p=0.410, respectively) (Table 6).

Satiety

After consumption of the snack containing vegetable crisps, the absolute changes in satiety scores over time were -0.115 ± 2.757, -1.97±2.353, and -0.88±2.360 cm at the 120th, 150th, and 180th minutes, respectively. After consumption of the snack containing apple, the absolute changes in satiety scores were 3.57±2.211, 2.185±1.784, and 1.02±2.345 cm at the 120th, 150th, and 180th minutes, respectively. The absolute changes in satiety scores over time were evaluated between the vegetable crisp and apple interventions. No significant differences were observed in satiety changes from 0–120 minutes, 0–150 minutes, and 0–180 minutes after consumption of vegetable crisps versus apple (p=0.138, p=0.706, p=0.912, respectively) (Table 6).

Desire to Eat

After consumption of the snack containing vegetable crisps, the absolute changes in desire-to-eat scores over time were -0.055±3.228, 2.24±2.848, and 0.265±2.536 cm at the 120th, 150th, and 180th minutes, respectively. After consumption of the snack containing apple, the absolute changes in desire-to-eat scores were -2.895±2.474, -2.02±3.000, and 2.835±3.525 cm at the 120th, 150th, and 180th minutes, respectively. The absolute changes in desire-to-eat scores over time were statistically evaluated between the vegetable crisp and apple interventions. No significant differences were observed in desire-to-eat changes from 0–120 minutes, 0–150 minutes, and 0–180 minutes after consumption of vegetable crisps versus apple (p=0.978, p=0.482, p=0.131, respectively) (Table 6).

Prospective Food Consumption

Among normal-weight individuals, the absolute changes in prospective food consumption scores after consumption of the snack containing vegetable crisps were 0.11±2.556, 2.12±2.772, and 0.23±2.392 cm at the 120th, 150th, and 180th minutes, respectively. After consumption of the snack containing apple, the absolute changes were -2.77±1.919, -2.34±2.114, and -0.84±1.768 cm at the 120th, 150th, and 180th minutes, respectively. The absolute changes in prospective food consumption scores over time were statistically evaluated between the vegetable crisp and apple groups. No significant differences were found in

prospective food consumption changes from 0–120 minutes, 0–150 minutes, and 0–180 minutes after consumption of vegetable crisps versus apple (p=0.823, p=0.071, p=0.124, respectively) (Table 6).

Table 6. Absolute changes in participants' VAS scores over time

Parameters	Interventions	0-120.min Mean ± SD	0-150.min Mean ± SD	0-180.min Mean ± SD
Hunger (cm)	**VC**	-3.605±2.630	4.595±2.352	0.875±2.830
	A	-3.735±2.232	-2.51±1.489	-0.985±2.496
	p	0.999	0.596	0.410
Satiety (cm)	**VC**	-0.115±2.757	-1.97±2.353	-0.88±2.360
	A	3.57±2.211	2.185±1.784	1.02±2.345
	p	0.138	0.706	0.912
Desire to Eat (cm)	**VC**	-0.055±3.228	2.24±2.848	0.265±2.536
	A	-2.895±2.474	-2.02±3.103	2.835±3.525
	p	0.978	0.482	0.131
Prospective Food Consumption (cm)	**VC**	0.11±2.556	2.12±2.772	0.23±2.392
	A	-2.77±1.919	-2.34±2.114	-0.84±1.768
	p	0.823	0.071	0.124

VC: Vegetable crisps**, A:** Apple

***Ad Libitum* Energy Intake**

Participants' ad libitum energy intake at lunch after consuming the snack containing vegetable crisps was 623.4±195.835 kcal. After consuming the snack containing apple, ad libitum energy intake at lunch was 665.455±240.344 kcal (Table 7). No significant difference was found between ad libitum energy intake after consumption of vegetable crisps and after consumption of apple (p=0.299).

Table 7. *Ad libitum* energy intake of participants after snack interventions

Intervention	Energy (kcal) Mean ± SD
VC	623.4±195.835
A	665.455±240.344
p	0.299

VC: Vegetable crisps**, A:** Apple

Discussion

In this study, the effects of two snack interventions with similar energy content but differing in protein and fiber content on postprandial blood glucose and subjective appetite parameters were investigated in young adults. The main findings of the study indicate that in healthy young adults, postprandial blood glucose and subjective appetite parameters did not show statistically significant differences after consumption of a snack containing fresh apple compared to a snack containing vegetable crisps. A minor finding was that at the 150th minute, prospective food consumption was higher after consuming vegetable crisps compared to apple. However, this difference was not statistically significant.

The relationship between snack consumption and obesity and weight control has been the subject of various studies (13,14). In this context, one study demonstrated that snack consumption in the evening has a more detrimental effect on weight management compared to snacks consumed at other times of the day (15). Furthermore, a review examining the effects of the energy content of snacks reported that consumption of energy-dense snacks may contribute to weight gain (13). In a crossover study conducted by Kim et al., the focus was on the fiber content of snacks, and the results indicated that consumption of high-fiber snacks suppressed blood glucose levels (16). Additionally, Masatomi et al. reported that a snack consumed 2 hours before an evening snack exerted a suppressive effect on postprandial blood glucose (17). In our study, we investigated the effects of a standard snack consumed after breakfast and freeze-dried vegetable crisps on postprandial glucose levels. Unlike previous studies, we did not observe a suppressive effect of the higher-fiber snack on postprandial blood glucose. This difference may be due to the fact that we did not monitor blood glucose levels after the lunch meal, as our study did not include post-lunch glucose follow-up.

The persistence of satiety after food consumption is an important factor in suppressing overeating, which can lead to overweight and obesity. In this context, identifying eating habits and foods that support satiety without significantly increasing total energy intake is important for promoting healthier eating behaviors (18). Snack consumption between meals can potentially promote satiety and suppress overeating at the subsequent meal (19). The results of

a study examining the effects of snack type on satiety showed that a fruit snack consisting of dried plums provided greater satiety compared to low-fat cookies; however, food intake two hours after snack consumption was not significantly affected (20). In addition, compared with control biscuits, biscuits enriched with barley β-glucan resulted in decreased desire to eat and increased satiety and fullness (21). Another study compared dried plums consumed as a pre-meal snack with an isoenergetic bread product of equal weight and reported lower hunger, desire to eat, and motivation to eat at all time points between snacks and meals (22). In our study, when comparing apple and vegetable crisps as snacks in healthy young adults, we did not observe an effect on postprandial satiety. However, at the 150th minute, we observed that prospective food consumption was higher after vegetable crisp consumption compared to apple. Differences between our findings and previous studies may be attributed to the type of dietary fiber predominant in the vegetable chips (mainly insoluble fiber), which exerts a less pronounced effect on gastric emptying and satiety compared to soluble fibers such as pectin. In addition, processing methods can alter the physicochemical properties of fibers and phytochemicals, thereby affecting bioavailability and subsequent appetite responses. For example, hot-air drying may reduce the viscosity of soluble fibers and diminish their satiating potential, whereas freeze-drying better preserves the structural integrity and functional properties of fiber. Such factors may explain why the satiety effect observed in our study differed from those reported in interventions using fresh or minimally processed vegetables.

Our study has several strengths. First, it was designed as a randomized crossover trial. Second, to the best of our knowledge, this is the first study to investigate the postprandial effects of freeze-dried vegetable crisps compared with a standard snack such as fresh apple. However, our study also has some limitations. These include the small sample size and the lack of follow-up for blood glucose and subjective appetite parameters after lunch.

Conclusion

In conclusion, our study found no differences in blood glucose levels, subjective appetite parameters, or ad libitum energy intake between the consumption of freeze-dried vegetable crisps and fresh apple as snacks. Snack consumption plays an important role in weight management, and further clinical studies are needed to identify different types of foods that may contribute to this process.

Abbreviations

BMI: Body Mass Index

VAS: Visual Analog Scala

WHO: World Health Organization

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Ethical Approval: The Clinical Research Ethics Committee of University of Health Sciences Gülhane Training and Research Hospital approved the study protocol. All procedures in the study were conducted in accordance with the Declaration of Helsinki.

Data Availability Statement*:* The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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