

Effectiveness of potato cream soup with tempeh, quail eggs, and isolated soy protein on blood glucose and lipid profiles of prediabetic subjects

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ABSTRACT

Background and Objectives: Prediabetes is a critical condition that increases the risk of developing type 2 diabetes mellitus and other chronic diseases such as cardiovascular disease. The purpose of this study was to analyze the effectiveness of potato cream soup with tempeh, quail eggs, and ISP on blood glucose and lipid profiles in subjects with prediabetes.

Methods and Study Design: The study was conducted in two stages: 1) determination of intervention formulation based on preliminary research, evaluation of nutritional content, glycemic index (GI), and glycemic load (GL) of instant potato cream soup. Product development in early-stage research using a completely randomized design (CRD); 2) An intervention using instant potato soup in subjects with prediabetes was conducted using a randomized controlled trial (RCT) design involving 27 prediabetic subjects aged 19–59 years. The subjects were divided into two groups: a control group of 14 subjects and an intervention group of 13 subjects. Data were analyzed using an independent sample t-test with a significance level of 0.05.

Results: The treatment group (SK3) significantly improved insulin sensitivity, as evidenced by a decrease in fasting insulin levels and HOMA-IR scores. The control group (SK0) showed significant improvement in FBG reduction and HOMA- β increase.

In terms of lipid profile, the SK3 intervention significantly increased total cholesterol and LDL levels, while the control group experienced a decrease. No statistically significant differences in changes were found between the two groups for 2hPPBG, HDL, and triglycerides.

Conclusions: In conclusion, SK3 formulation has potential as a functional food for prediabetes management through improved insulin sensitivity.

KEYWORDS

Blood glucose, glycemic index, lipid profile, potato soup, prediabetes.

INTRODUCTION

The global increase in the prevalence of prediabetes across various age groups, from children to adults in various countries, has become a serious public health challenge because of the high risk of transitioning to type 2 diabetes mellitus (T2DM) in a short period of time¹. As a complex metabolic disorder, prediabetes is not only characterized by hyperglycemia, but is also often accompanied by dyslipidemia due to insulin resistance, which involves increased triglycerides and LDL cholesterol and decreased HDL². This abnormal lipid profile significantly accelerates the atherosclerosis process, thereby increasing the risk of cardiovascular diseases such as myocardial infarction and stroke, even before progressing to DMT2. A strategic approach to reduce the risk of clinical transition to DMT2 and cardiovascular disease in the globally increasing prediabetic population involves early detection and comprehensive metabolic management, targeting the simultaneous regulation of glycemic control and lipid profiles.

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The limitations of pharmacological therapy in the management of long-term chronic diseases, particularly in relation to the risk of systemic side effects and low patient compliance, have prompted the need for safer alternative approaches³. Functional foods have the potential to provide a strategic complementary solution through bioactive compounds that can modulate metabolic pathways, provide anti-inflammatory effects, and regulate glucose and lipid levels with a better safety profile than chemical drugs⁴. Although the consumption of functional foods has been shown to have the potential to sustainably manage cardiometabolic disorders in a sustainable manner, further research is needed to validate the mechanisms of action and clinical evidence⁵. Therefore, the development of functional food-based dietary interventions is crucial for current therapies, reducing the limitations of conventional drugs, and optimizing the safety of chronic disease management^{4,5}.

Various instant functional food products have been studied to support the health of people with diabetes mellitus (DM). These include low-glycemic-index snack bars made from a blend of sago starch, tempeh, and black rice⁶, as well as galohgor products (cakes and beverage powders) that have a positive effect on body fat and lipid profiles in patients with type 2 diabetes⁷. Other supporting research has also developed tempeh-enriched pumpkin cream soup for the elderly⁸, diabetic snacks made from a combination of sago and tempeh⁹, and the use of instant pumpkin soup for diabetes therapy¹⁰.

The potential of potatoes, tempeh, quail eggs, and isolated soy protein (ISP) has been extensively studied separately. Research on the effectiveness of their combination in whole dishes, such as cream soups, is still very limited. Current literature tends to focus on the functional benefits of tempeh for metabolic health or the nutritional value of other ingredients separately, thereby overlooking the possibility of synergistic nutritional interactions within a single culinary menu. Consequently, there is an urgent need for systematic studies to evaluate the impact of this integrated diet on the management of cardiometabolic conditions and chronic disease risk^{11,12}. Clinical validation of these combination dishes is crucial to ensure that dietary interventions are not only safe, but also provide optimal health benefits compared to consuming individual ingredients. Isoflavones and peptides in soy-based products, such as tempeh and ISP, play strategic roles in increasing insulin sensitivity and improving lipid homeostasis through various molecular mechanisms. Although the impact on fasting glycemia varies owing to individual bioavailability factors, the synergy between peptides and isoflavones provides a strong protective effect against metabolic syndrome and cardiovascular disease¹³.

Potatoes (*Solanum tuberosum* L.) are potential functional food ingredients because of their complex starch content (amylose and amylopectin) and phytochemical profile rich in

fiber, minerals, and antioxidants¹⁴. Through advanced technological modifications, such as physical treatments, such as *heat moisture treatment* and gamma radiation, the resistant starch (RS) content in potatoes can be increased to lower the glycemic index and slow enzymatic hydrolysis. The integration of this modified potato starch is not only effective in regulating blood sugar and improving insulin sensitivity through the production of short-chain fatty acids (SCFA) by gut microbiota but also provides protection against oxidative stress and reduces the risk of dental caries^{15,16}.

The use of quail eggs in moderate portions as a component of dishes, such as cream soup, can increase nutritional density without worsening plasma lipid profiles, even though they are often considered a high-cholesterol food¹⁷. Quail eggs are rich in high-quality protein and essential micronutrients, such as vitamin A, B complex, iron, selenium, and *choline*, which support nerve function and lipid metabolism through the body's cholesterol homeostasis mechanism. This nutrient-dense composition makes quail eggs a food ingredient that can enhance the nutritional value of meals without a significant risk of metabolic disorders when consumed in appropriate amounts as part of a healthy diet.

This study emphasizes innovation through a *whole-food approach*, which is considered to be more applicable to the community than the use of single nutritional supplements. By relying on a diverse diet, this approach provides a complete spectrum of nutrients and bioactive compounds that work synergistically to improve overall clinical conditions. The implementation of a whole-food-based strategy has been proven to improve diet quality, patient compliance, and the sustainability of long-term health interventions, because it aligns with natural daily eating habits.

This study specifically aimed to prove the clinical effectiveness of cream soup in lowering blood glucose levels and improving lipid profiles in subjects with prediabetes. Through this approach, we hope that strong scientific evidence will be available regarding strategic dietary interventions that can be clinically applied to improve the metabolic health of the prediabetic population in a sustainable manner. Research on dietary and pharmacological interventions in prediabetic subjects has been widely conducted. Controlled randomized clinical trials that specifically test the effectiveness of instant potato cream soup on blood glucose and lipid profiles in prediabetic subjects are limited. The purpose of this study was to analyze the effectiveness of potato cream soup containing tempeh, quail eggs, and isolated soy protein (ISP) on blood glucose and lipid profiles in prediabetic subjects.

MATERIALS AND METHODS

Materials

The ingredients used to make instant potato cream soup were quail egg meal obtained from CV. Slamet Quail Farm,

Tempeh obtained from PT Azaki Food International, Granola L. potato variety obtained from the potato plantation of Kerinci Regency, Jambi Province, ISP obtained from PT Aneka Sarivita, onion, spring onion, celery, chicken feet broth, pepper, salt, fresh cream, and unsalted butter. Making instant cream soup based on Dari *et al*¹⁸. This study used animal protein source (quail egg flour), vegetable protein source (tempeh and ISP) and carbohydrate source (potato). The instant potato cream soup formula is presented in Table 1.

Table 1. Instant potato cream soup formula

Substance	Unit	Formula	
		SK0	SK3
White Stock (300 ml)	g	308	308
Onion	g	40	40
Leeks	g	20	20
Celery	g	8	8
Unsalted butter	g	1	1
Pepper	g	0,46	0,46
Salt	g	1	1
Fresh Cream	g	20	20
Potatoes	g	224	200
Quail egg flour	g	0	5
Tempeh	g	0	14
Isolated soy protein (ISP)	g	0	5
Total	g	622,46	622,46

Design, Time, and Place

This study consisted of two stages: 1) determining the intervention formulation based on preliminary research, evaluation of nutritional content, glycemic index (GI), and glycemic load (GL) of instant potato cream soup, and 2) intervention with instant potato cream soup for subjects with prediabetes. Product development in the initial stage of the study used a completely randomized design (CRD). The instant potato cream soup intervention used a randomized controlled trial (RCT) design to examine the effectiveness of administering instant potato cream soup with the addition of tempeh, quail egg flour, and ISP to prediabetic subjects. The GI tests were conducted on 11 healthy respondents. The clinical trial was

conducted on prediabetic subjects over 28 days with two intervention groups: a control group given 54 g of instant potato cream soup without any added ingredients (SK0), and a treatment group given 45 g of instant potato cream soup with added quail egg flour, tempeh, and ISP (SK3). Nutritional content testing was conducted at the Bogor Industry Standardization and Service Center Laboratory and *MBrio Food Laboratory*. GI and GL tests were conducted at the Clinical Nutrition Laboratory, Department of Community Nutrition, IPB University. Blood glucose and lipid profiles were measured at the Bogor City Health Laboratory and Physiology Laboratory, Faculty of Medicine, Brawijaya University.

Ethical Approval

Before conducting clinical trials, the researchers submitted an ethical clearance application to the Ethics Committee of the Jambi Ministry of Health Polytechnic and received approval No. LB.02.06/2/0079/2024.

Tools and Materials

The equipment used in this study included a drum dryer, stove, knife, cutting board, spatula, blender, sealer, scale, pot, oven, furnace, desiccator, condenser, Soxhlet extractor, Kjeldahl flask, distillation apparatus, Erlenmeyer flask, high-performance liquid chromatography (HPLC), and gas chromatography-mass spectrometry (GC-MS). The materials used in this study were cream soups prepared by researchers based on the results of research on the development of instant potato cream soups¹⁸. Quail egg flour (QEF) was obtained from CV. Slamet Quail Farm, tempeh was obtained from PT *Azaki Food International*, Granola L. potato variety was obtained from a potato plantation in Kerinci Regency, Jambi Province, Indonesia, ISP was obtained from PT Aneka Sarivita, onion, spring onion, celery, *white stock*, pepper, salt, *fresh cream*, and *unsalted butter*.

Research Subjects

The research subjects consisted of 27 individuals who were prediabetic, female, aged 19-59 years, not currently hospitalized, not pregnant, had no history of complications other than hypercholesterolemia and hypertension, were non-smokers, had not yet reached menopause, and were willing to sign an informed consent form. The participants were from the Dramaga Community Health Center, Bogor Regency, West Java, Indonesia. Before the intervention began, respondents underwent screening to identify subjects with prediabetes. The screening involved measuring fasting blood glucose and 2-hour postprandial blood glucose levels through fingerstick blood samples. A person is considered to have prediabetes if their fasting blood glucose is between 100–125 mg/dL and/or their 2-hour postprandial blood glucose is between 140–199 mg/dL.

Administration of Potato Cream Soup

The provision of instant potato cream soup was based on the *Food Standards Agency*¹⁹ with a snack proportion of 20% for two snacks per day. In this study, instant cream soup was given in the morning or afternoon as a snack, once a day, equivalent to 215 kcal (based on the calculation of daily calorie requirements for adults of 2150 kcal, $10\% \times 2150 \text{ kcal} = 215 \text{ kcal}$). Based on the nutritional content calculations, 54 g of instant potato cream soup was given for SK0 and 45 g for SK3 (dw).

Type and Method of Data Collection

The data collected in this study included subject characteristics, such as age, occupation, highest level of education, and gender, which were obtained through interviews. During the cream soup intervention phase, data were collected twice: before the intervention (day 0) and after the intervention (day 28). Anthropometric data included body weight (BW) and body mass index (BMI). Blood glucose profiles included fasting blood glucose (FBG), 2-hour *postprandial* blood glucose (2hPPBG), fasting insulin, HOMA-IR, and HOMA- β . Lipid profiles included total cholesterol, triglyceride, LDL, and HDL levels. Data on subject compliance with cream soup consumption were collected through observations and interviews. Subjects fasted for 10 h, and blood sampling was conducted at Ciherang Village and Sukawening Village Health Posts, Dramaga District, Bogor Regency, Indonesia.

Data Analysis

The data obtained were processed using *Microsoft Excel 2019 for Windows* and analyzed using *Statistical Program for Social Science (SPSS 26.0 for Windows)*. The intervention data were processed using an *independent T-test* to determine the potential of instant potato cream soup to control blood glucose and lipid profiles. The significance level was set in this study < 0.05 .

RESULTS AND DISCUSSION

Determination of Intervention Products

Based on the results of preliminary research conducted by Dari *et al.*¹⁸, there were four formulas: SK0/control (potato cream soup), SK1 (potato cream soup with tempeh), SK2 (potato cream soup with ISP), and SK3 (potato cream soup with tempeh, quail eggs, and ISP). The intervention formulation was determined based on hedonic/liking tests, *descriptive/quantitative description analysis* (QDA), GI and GL values, and nutritional content. The formulations selected to proceed to the intervention stage were SK0 (potato cream soup) as the control and SK3 (potato cream soup with tempeh, quail eggs, and ISP) as the treatment. The potato cream soup was dried using a *drum dryer* so that the final product was in powder form.

Nutritional Content Evaluation

The average nutritional content of cream soups is presented in Table 2. The results of the protein and ash content

Table 2. Average nutritional content of potato cream soup and average carbohydrate composition of potato cream soup

Nutritional Content	Sample		<i>p</i>
	SK0	SK3	
Moisture Content (g/100 g)	5.70 $\pm$ 2.77	3.65 $\pm$ 0.59	0.236
Protein (g/100 g)	11.38 $\pm$ 0.16	20.00 $\pm$ 0.49	<0.001
Fat (g/100 g)	9.69 $\pm$ 0.99	23.85 $\pm$ 14.33	0.396
Ash Content (g/100 g)	5.36 $\pm$ 0.04	4.62 $\pm$ 0.03	<0.001
Total Carbohydrates (g/100 g)	67.88 $\pm$ 3.37	48.14 $\pm$ 15.30	0.309
Dietary Fiber (g/100 g)	24.89 $\pm$ 4.45	21.89 $\pm$ 1.03	0.272
Available Carbohydrates (g/100 g)	42.99 $\pm$ 2.08	26.26 $\pm$ 14.03	0.336
Total Calories (kcal)	404.23 $\pm$ 13.28	487.19 $\pm$ 49.56	0.335
Starch (g/100 g)	5.70 $\pm$ 2.77	3.65 $\pm$ 0.59	<0.001
Amylose (g/100 g)	11.38 $\pm$ 0.16	20.00 $\pm$ 0.49	0.176
Amylopectin (g/100 g)	9.69 $\pm$ 0.99	23.85 $\pm$ 14.33	0.001

SK0 = control (potato cream soup); SK3 = treatment (potato cream soup with tempeh, quail eggs, and ISP); ISP = isolated soy protein.

analyses showed statistically significant differences between the groups. The average protein content of SK3 sample (20.00 g/100 g) was significantly higher than that of SK0 (11.38 g/100 g). The ash content of SK0 sample (5.36 g/100 g) was significantly higher than that of SK3 (4.62 g/100 g). The variables moisture content, fat, total carbohydrates, dietary fiber, available carbohydrates, and total calories did not show any significant differences ($p>0.05$). The formulations of SK0 and SK3 met the SNI 01-4967-1999 standards for cream soup, with a minimum protein content of 10%, fat content of 5%, and moisture content of 8%. The increase in the protein content in SK3 was due to the addition of high-protein raw materials. Increasing the protein content of a product can reduce its mineral content.

The average carbohydrate composition of the cream soups is presented in Table 2. The results of the analysis showed that the starch content was significantly higher in SK0 than in SK3. The amylopectin content of SK3 was significantly higher than that of SK0. Amylose content did not differ significantly between the SK0 and SK3 groups. The analysis results showed that the total starch content in the control formula (SK0) was significantly higher than that in SK3 because of the use of potatoes as the main carbohydrate base, whereas the addition of tempeh, quail eggs, and ISP in SK3 causes dilution of the total starch proportion and triggers complex interactions between proteins or fats and the starch structure¹⁴. Although the total starch content decreased, the amylopectin content in SK3 increased significantly because

of the contribution of additional ingredients or enzymatic activity of tempeh, which modified the starch structure during processing^{14,20}. The amylose content remained stable in both formulations because its linear polymer nature tends to be constant with the addition of small amounts of ingredients without intensive enzymatic treatment^{20,21}. This mechanism reflects how the interaction between the original potato components and nutrients from the additives affects the stability and starch fraction ratio of the final cream soup product^{14,20}.

Evaluation of Glycemic Index (GI) and Glycemic Load (GL)

Figure 1 shows a graph visualizing changes in blood glucose levels at 0, 15, 30, 45, 60, 90, and 120 min after consuming the standard food (glucose) and test food (instant potato cream soup). Analysis of the blood glucose response showed that the SK3 sample produced lower and more stable glucose levels compared to the standard food and SK0 sample, resulted in the highest glucose spike. The GI test results indicated that all soup variants had low GI values, with no significant differences between samples (<55). The low GI values were influenced by the composition of ingredients, such as fat, protein, and the formation of resistant starch during processing. Instant potato cream soup, with or without the addition of tempeh, ISP, and quail egg flour, has the potential to be developed as a functional food that is effective in controlling glycemic response.

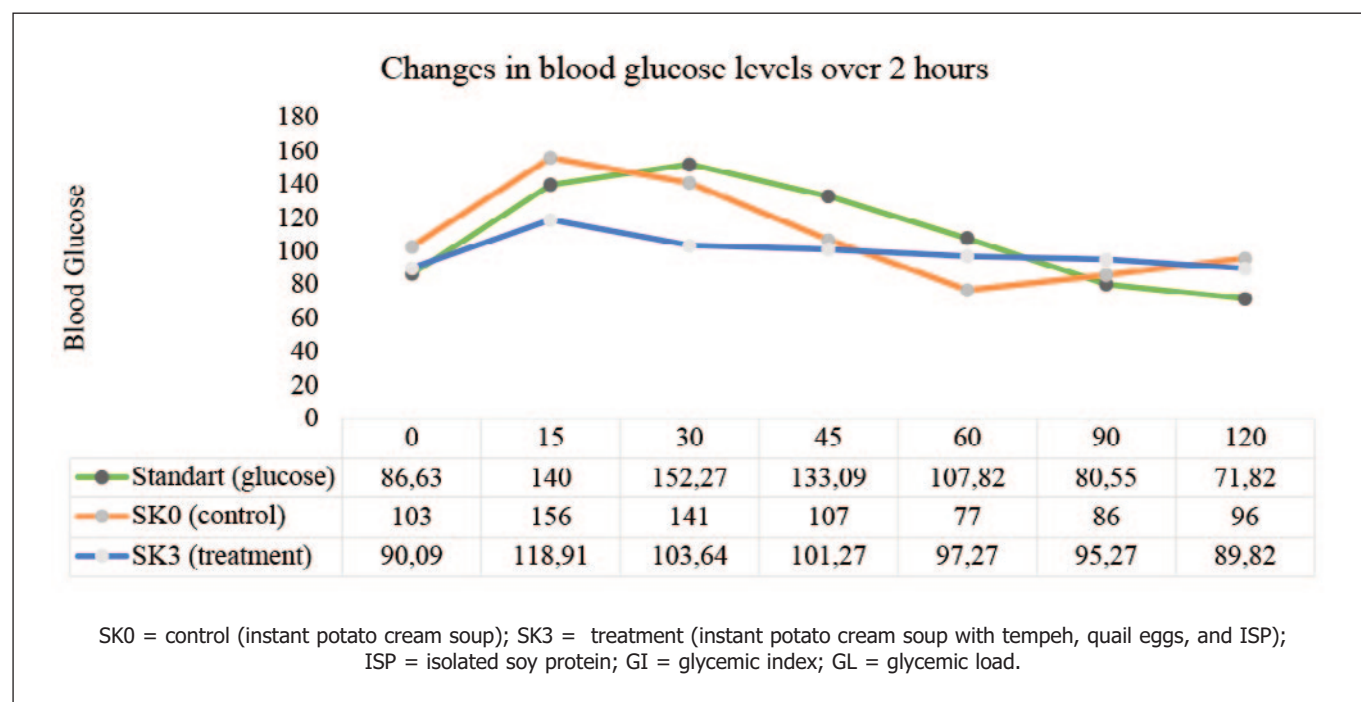


Figure 1. Changes in blood glucose levels over 2 hours

The results of GI and GL testing of instant potato cream soup are shown in Figure 2. The results of this study show that treatment administered to the SK3 group can reduce GI and GB values. The GI value decreased from 31.74 in the SK0 group to 27.93 in the SK3 group. The GL value decrease from 21.54 to 13.38. The GL value of SK0 was in the high category (≥ 20), whereas SK3 was in the moderate category (11-19). These results indicate the potential of SK3 to modulate the glycemic response. The low GI value of instant potato cream soup compared to whole potatoes, both with and without the addition of tempeh, ISP, and quail egg flour, was due to the processing and composition of the ingredients. The fat and protein contents in cream soup and the addition of tempeh, ISP, and quail egg flour can slow down the digestion of carbohydrates.

The decrease in GI and GL values in the SK3 formula compared to the control (SK0) was due to the addition of tempeh, quail eggs, and ISP, which modified the physical and chemical structure of starch by increasing amylopectin or thermal treatment, thereby inhibiting enzymatic degradation and slowing the release of glucose into the bloodstream. The dietary fiber and protein contents of these ingredients play a role in reducing the levels of rapidly digestible carbohydrates and slowing glucose absorption²². The use of these high-fiber and high-protein ingredients, combined with the formation of resistant starch during cream soup processing, effectively lowered the GI from high to moderate. These efforts to control the glycemic profile provide significant health benefits, particularly in managing blood glucose levels in diabetic patients and reducing the risk of health complications, such as inflammation, low HDL cholesterol, and hyperglycemia.

Subject Characteristics

The subject characteristics are presented in Table 3. The subject characteristics showed high homogeneity for several variables. All participants (100%) in this study were women who worked as housewives. The average age of the control group (40.93 ± 6.17 years) was almost the same as that of the treatment group (40.23 ± 6.55 years). There was little variation in educational background, with most subjects in the control group being elementary school graduates (57.1%), while the distribution of education in the treatment group was even, with the highest proportion being high school graduates (38.5%).

The average FBG value for the control group was 101.64 and for the treatment group was 93.62. The average 2hPPBG value for the control group was 146.57 and for the treatment group was 151.77. The average FBG score of the control group and 2hPPBG score of both groups fell within the prediabetes category.

Compliance with Potato Cream Soup Consumption

Subject compliance in consuming instant potato cream soup during the intervention period (four weeks) is presented in Figure 3 and shows the differences between the treatment and control groups. The treatment group consistently showed stable compliance levels, reaching 100% in the first and fourth weeks and experiencing only a slight decline in the second (97.8%) and third (98.9%) weeks. The control group showed lower compliance levels than did the treatment group, with the lowest compliance in the second week (83.67%). The control group showed an upward trend in

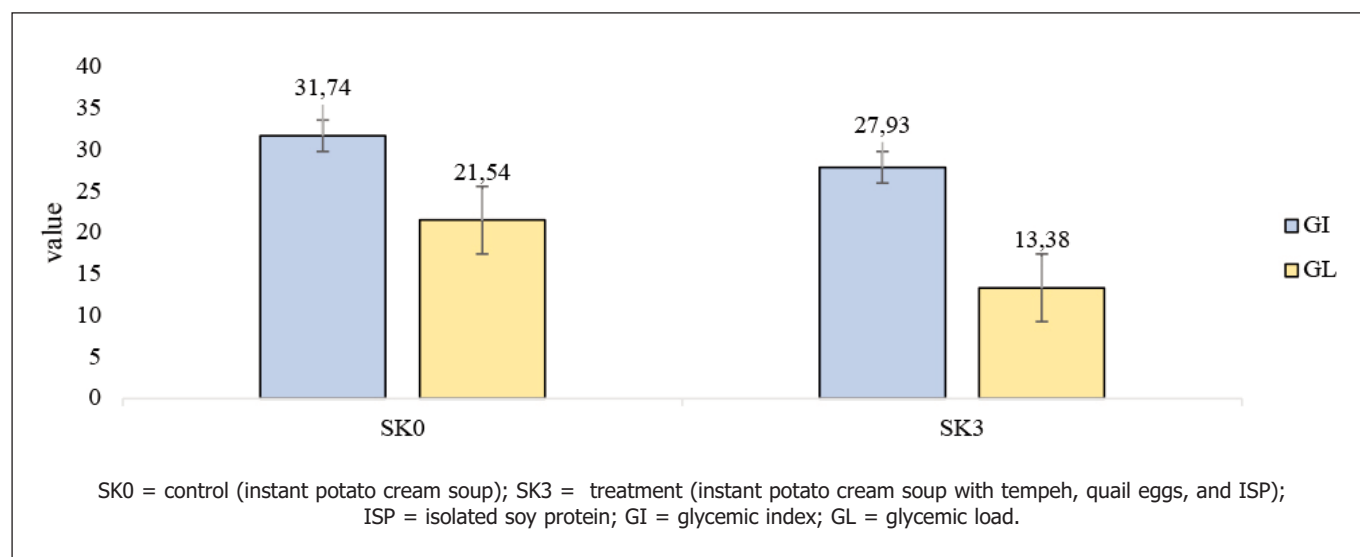


Figure 2. Results of glycemic index and glycemic load analysis of potato cream soup

Table 3. Subject Characteristics and Distribution of Participants Based on FBG and 2hPPBG screening

Variable		Control		Treatment	
		n	%	n	%
Education	Never attended school	0	0	0	0
	Did not complete elementary school/equivalent	0	0	1	7
	Elementary school graduate or equivalent	8	57.1	4	30.8
	Completed junior high school/equivalent	1	7.1	3	23.1
	High school graduate/equivalent	5	35.7	5	38.5
	Total	14	100	13	100
Age	Adult	14	100	13	100
	Total	14	100	13	100
	Mean±SD	40.93±6.17		40.23±6.55	
Gender	Male	0	0	0	0
	Women	14	100	13	100
	Total	14	100	13	100
Occupation	Housewife	14	100	13	100
	Total	14	100	13	100
FBG	Normal	6	42.9	8	61.5
	Prediabetes	8	57.1	5	38.5
	Diabetes	0	0	0	0
	Total	14	100	13	100
	Mean±SD	101.64±10.93		93.62±151.77	
2hPPBG	Normal	4	28.6	4	30.8
	Prediabetes	10	71.4	9	69.2
	Diabetes	0	0	0	0
	Total	14	100	13	100
	Mean±SD	146.57±27.08		151.77±28.93	

n = number of subjects; adults = 19-58 years old; FPG = fasting plasma glucose; 2hPPG = 2-hour *postprandial* glucose.

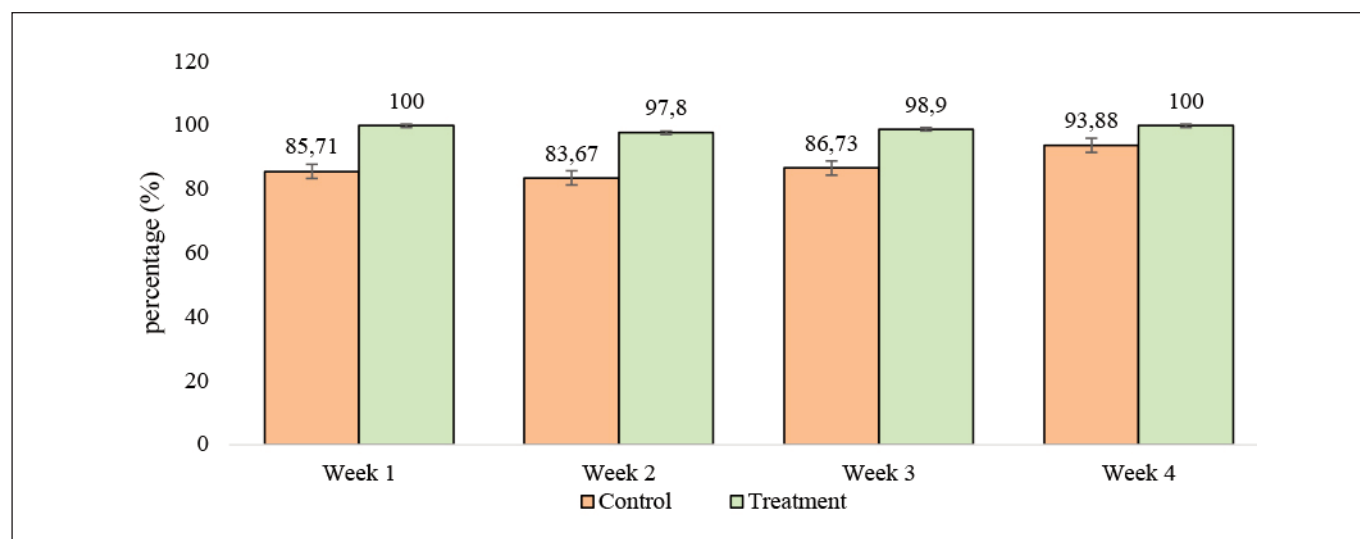


Figure 3. Percentage of subjects' compliance

compliance over time, peaking in the fourth week with a significant increase to 93.88%. The results of this study indicated that the treatment was appeared to be effective in maintaining patient compliance. Some subjects did not consume 100% in both groups because they forgot to consume it, felt full after consuming other foods, and did not bring it to work or travel/daily activities.

Effect of Instant Potato Cream Soup Consumption on Subject Anthropometry

The effects of instant potato cream soup consumption on the anthropometry of subjects in the control and treatment groups are presented in Table 4. The results of this study found no significant effect of instant potato cream soup consumption on changes in the participants' weight and BMI ($p > 0.05$). However, the group that consumed SK0 (control group) experienced a greater decrease in body weight (BW) and BMI than did the treatment group (SK3). The SK0 sample given to the control group had lower protein and fat contents than SK3, resulting in lower calorie intake and contributing to a decrease in BW and BMI. The SK3 sample, with

the addition of tempeh, quail egg flour, and ISP, had higher protein and fat content than SK0, which had the potential to increase calorie intake and energy efficiency, thereby neutralizing the effect of weight loss. This increase in macronutrient intake could also increase *satiety* and reduce calorie deficit without directly causing significant changes in BMI directly. The greater weight and BMI loss in the control group (SK0) compared to the SK3 group was related to the addition of ingredients such as tempeh, quail eggs, and ISP to the SK3 formula, which increased energy and protein density, thereby affecting the subjects' calorie balance and metabolism. Changes in body composition through ready-to-eat food interventions require stricter dietary control and a longer period for significant metabolic effects to be observed²³.

The Effect of Potato Cream Soup Consumption on Blood Glucose Profile

The average decrease in the blood glucose profile is presented in Table 5. The results of the analysis showed that the treatment group had significantly improved insulin sensitivity, as evidenced by a decrease in fasting insulin levels ($p < 0.001$) and

Table 4. Average anthropometric changes in subjects based on the treatment group

Anthropometry	Control group	Treatment group	p
	Δ	Δ	
BW	(-)1.06 $\pm$ 2.54	(-)0.47 $\pm$ 1.33	0.461
BMI	(-)0.47 $\pm$ 1.12	(-)0.18 $\pm$ 0.59	0.425

BW = body weight; BMI = body mass index; Δ = delta change before and after intervention; p = difference between Δ control group and intervention group in *independent sample t-test*.

Table 5. Average changes in blood glucose profiles and lipid profiles of the subjects

Variables	Control group	Treatment group	p
	Δ	Δ	
Blood glucose profiles			
FBG (mg/dL)	(-)17.86±9.73	(-)9.15±11.60	0.044
2hPPBG (mg/dL)	(-)49.14±33.71	(-) 27.15±23.34	0.062
Fasting insulin (mIU/L)	(-)0.93±2.48	(-)5.05±2.73	<0.001
HOMA-IR	(-)0.61±0.54	(-)1.26±0.72	0.013
HOMA-β (%)	80.71±90.07	(-) 34.01±58.93	< 0.001
Lipid profiles			
Total cholesterol (mg/dL)	(-)12.43±18.84	14.15±19.60	0.001
HDL (mg/dL)	2.29±6.79	(-)0.62±16.68	0.554
LDL (mg/dL)	(-)18.50±18.36	13.69±26.47	0.001
Triglycerides (mg/dL)	18.50±40.80	5.23±29.41	0.345

FPG = fasting plasma glucose; 2hPPG = 2-hour *postprandial* plasma glucose; Δ = delta change before and after intervention; HOMA-IR = *Homeostatic Model Assessment of Insulin Resistance*; HOMA- β = *Homeostatic Model Assessment of β -Cell function*; HDL= *high-density lipoprotein*; LDL = *low-density lipoprotein*; p = difference between Δ in the control and intervention groups in the *independent sample t-test*.

higher HOMA-IR scores ($p=0.013$). The control group showed significant improvement in FBG levels ($p=0.044$) and increased beta cell function, as measured by HOMA- β ($p<0.001$). The changes in 2hPPBG were not significantly different between the two groups ($p=0.062$). The control (SK0) and treatment (SK3) groups were effective in reducing FBG and 2hPPBG levels. The metabolic mechanisms underlying these improvements involve different pathways. The treatment group (SK3) showed improved metabolic efficiency through increased insulin sensitivity, as evidenced by a decrease in HOMA-IR and higher fasting insulin levels compared to the control group. This increased sensitivity reduces the functional load of pancreatic β -cells (HOMA- β). The control group (SK0) achieved normoglycemia through a compensatory pathway, characterized by improved HOMA-IR and increased HOMA- β . This condition indicates an increase in pancreatic workload to overcome the remaining resistance. Although both the control group (SK0) and the treatment group (SK3) were effective in reducing FBG and 2hPPBG levels, they did so via different metabolic pathways. The SK3 group demonstrated superior long-term efficiency through a significant increase in insulin sensitivity, marked by a decrease in HOMA-IR and fasting insulin levels, which directly reduced the functional load on pancreatic beta cells (HOMA- β) and protected them from the risk of exhaustion. The SK0 group (control) achieved normo-

glycemia through compensatory mechanisms characterized by increased HOMA- β , in which the pancreas is forced to work harder to overcome residual insulin resistance, thereby risking permanent beta cell damage in the long term^{24,25}.

Proteins and bioactive compounds from tempeh and quail eggs can reduce insulin resistance. Fibers from tempeh can improve gut health and inflammation. Micronutrients from quail eggs play a role in modulating insulin signaling. The control group also showed significant improvement, particularly in the reduction of FBG and improvement in β -cell function (HOMA- β), which was due to the low GI value of potato starch²⁶. There was no significant difference in the postprandial glucose response (2hPPBG) between the groups due to the subjects' dietary factors.

The significant increase in insulin sensitivity in the treatment group was due to the synergy of the various nutritional components. Soy proteins and amino acids from tempeh and ISP contributed to improved glycemic control. Isoflavone and antioxidant contents also help counteract oxidative stress, which triggers insulin resistance. This effect is reinforced by quail egg flour, which contains micronutrients, such as vitamin D, which can activate the glucose absorption pathway, thereby mimicking the action of insulin and improving its sensitivity²⁷. The integration of plant-based proteins, amino

acids, and the nutritional content of quail eggs has a greater impact on the treatment group.

The Effect of Potato Cream Soup Consumption on Lipid Profile

The average decreases in the lipid profiles of the control and treatment groups are presented in Table 5. The results of the analysis showed that the intervention caused a statistically significant increase in total cholesterol and LDL levels ($p=0.001$), whereas the control group experienced a decrease. No statistically significant differences were found in the HDL and triglyceride levels ($p>0.05$) between the intervention and control groups ($p > 0.05$).

Specific components of the SK3 formula, such as ISP and quail egg flour, are factors that can modulate lipid metabolism and cause an increase in cholesterol levels. The balance of macronutrients in the diet has a direct metabolic effect on the lipid pathways. Certain types of proteins and fats can increase endogenous cholesterol synthesis or inhibit its catabolism, which can elevate its concentration in the blood²⁸. The control group, which did not receive additional protein and fat intake, maintained or even had reduced LDL levels.

The significant increase in total cholesterol and LDL levels in the treatment group, despite no change in HDL and triglyceride levels, can be explained by the complex interaction of various factors. Contributing factors include the addition of quail egg powder, whose dietary cholesterol content can increase plasma cholesterol and whose macronutrient profile can enhance lipid absorption and synthesis. Soybean components such as ISP and tempeh may have varying effects because their protein effects depend on individual metabolic conditions. This food combination also has the potential to alter the composition of gut microbiota, which can affect lipid and cholesterol metabolism by modulating bile acids and systemic inflammation²⁹.

Limitations of the study

A limitation of this study is that the intervention lasted only 28 days, which was insufficient to detect changes in HbA1c levels; a study duration of at least.

Conclusion

Nutritional and glycemic evaluation of potato cream soup showed that the SK3 formulation with added tempeh, quail eggs, and ISP had the potential to lower GI and GL values. The results of the four-week intervention show that the treatment group showed significant improvement in blood glucose, insulin, and insulin sensitivity parameters compared to the control group. The SK3 formulation suggests that the product can be developed as a functional food for the management of prediabetes and DMT2 prevention. The findings of this study present a significant opportunity for the food in-

dustry to utilize the SK3 formula to develop a new line of functional ready-to-eat or ready-to-cook products.

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