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Research Article

Determination of the glycaemic index (GI) of corn noodles

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Abstract

The study was conducted to determine the glycaemic index (GI) of corn noodles. The study was conducted on 14 healthy adult volunteers, applying the method according to TCVN 10036: 2013 (ISO 26642: 2010). Data were processed using Microsoft Excel software and the results were evaluated according to the prescribed standards. The results showed that the research product had a glycaemic index (GI) of 58.0. Corn noodles are classified as foods with an average glycaemic index. The product has the potential to be used as a supplement in daily meals for people who need to control blood sugar levels (pre-diabetics, obese people).

Keywords: *GI, blood sugar, corn noodles.*

1. INTRODUCTION

Maize (Zea mays) is one of the most widely consumed cereal crops in the world. According to several studies, maize offers various health benefits, including the promotion of healthy digestion due to its dietary fiber content, support for vision through antioxidants such as lutein and zeaxanthin, and the provision of sustained energy from complex carbohydrates. Maize also contains B-group vitamins that contribute to brain and cardiovascular function, antioxidants that help protect cells from damage, and prebiotic fiber that supports the growth of beneficial intestinal microbiota. Maize can be consumed directly by boiling, steaming, or roasting, or it can be processed as a raw material for the production of food products. One of the currently emerging processing methods is the production of noodles from maize kernels. This approach both meets consumer preferences and contributes to diversifying the utilization of maize. Maize noodles facilitate storage and can be processed into a variety of food products.

Currently, metabolic diseases are increasing rapidly and have become a major public health concern not only in our country but also globally. Diabetes mellitus increases the risk of cardiovascular disease and metabolic disorders and can cause damage to multiple organs, including the kidneys, eyes, and nervous system, while obesity-characterized by excessive accumulation of body fat-has serious adverse health effects and is a leading cause of chronic conditions such as cardiovascular disease, diabetes mellitus, and hypertension. Alongside appropriate increases in physical activity, dietary intervention is recognized as one of the key factors in preventing and improving these metabolic conditions [1].

The glycaemic index (GI) of foods has been observed to be associated with the control of diabetes mellitus. The glycaemic index reflects the increase in blood glucose levels after the consumption of specific foods, relative to glucose as a reference. The value of the glycaemic index depends on the type and amount of carbohydrates present in foods, as well as the digestion process and the absorption of monosaccharides in the body. Dietary composition can reduce postprandial insulin secretion. Insoluble dietary fiber may play a role in blood glucose control by increasing the viscosity of gastrointestinal contents after meals, thereby slowing the rate of digestion [2].

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Maize is an agricultural crop that is widely cultivated in many regions of Viet Nam. Maize-based products are considered to have strong potential as an important source of carbohydrates. There is an increasing demand for foods with appropriate glycaemic index values that are able to provide nutrients and energy for the body while supporting blood glucose control, thereby contributing to the reduction of metabolic diseases. Therefore, this study was conducted to analyze the composition and glycaemic index of noodles produced from maize kernels, with the aim of providing recommendations for target consumer groups.

2. MATERIALS AND METHODS

2.1. Research subjects

Healthy adult volunteers were enrolled in the study and were required to meet the following criteria [3]:

- Selection criteria:

+ Age between 20 and 40 years

+ Fasting blood glucose < 5.6 mmol/L

+ Systolic blood pressure < 140 mmHg and diastolic blood pressure < 85 mmHg

+ No history of food allergy or food intolerance

Voluntary participation and compliance with the study requirements.

- Exclusion criteria:

+ Participants were excluded if they had been diagnosed with diabetes mellitus, impaired glucose tolerance, impaired fasting glucose, renal failure, hepatic failure, or intestinal obstruction.

+ Participants were excluded if they were experiencing acute conditions, including respiratory tract infections, gastrointestinal disorders, hypertension or hypotension, and cardiac arrhythmias.

+ Participants were excluded if they had experienced a severe illness or had undergone major surgery requiring hospitalization within the preceding three months.

+ Participants were excluded if they had consumed stimulants such as alcohol or beer within 12 h prior to the experiment.

+ Participants were excluded if they had a family history of diabetes mellitus.

In this study, a minimum analytical sample size of 15 participants was selected, with an expected recruitment of approximately 25 - 30 participants. This sample size met the requirements of TCVN 10036:2013 (ISO 26642:2010), which specifies the inclusion of at least 10 healthy subjects based on the established criteria.

2.2. Research methods

The study was designed as a cross-over clinical trial. The investigation was conducted in accordance with the standard method specified in TCVN 10036:2013 (ISO 26642:2010) to evaluate the glycaemic index of the maize noodle product.

Study period: From February 2025 to October 2025.

2.3. Research process

Participants were screened to determine eligibility for study enrollment. Study information was provided, and written informed consent was obtained from all participants using the Informed Consent Form (ICF). Each participant took part in three test sessions, including two sessions with the reference product (anhydrous glucose) and one session with the test product. Each session was separated by a minimum washout period of two days.

At treatment day: Participants arrived at the study site at 07:00 a.m. after an overnight fast and rested for 30 min. A clinical examination and a brief interview regarding health status were conducted. Baseline blood glucose was measured, followed by measurements at 15, 30, 45, 60, 90, and 120 min after consumption of the reference food or the test product. Participants rested for approximately 30 min, underwent a final health check, and the test session was then concluded.

2.4. Blood collection and blood glucose test

Capillary blood samples were collected from participants and analyzed using a standardized portable blood glucose meter, in accordance with the guidelines specified in TCVN 10036:2013 (ISO 26642:2010). The capillary blood glucose sampling procedure was strictly followed, including the selection of the sampling site, verification of participant identity, adherence to the scheduled sampling times, correct sample documentation, and ensuring the psychological comfort of the volunteers. The portable blood glucose meter (On Call Plus, ACON Laboratories, USA) was designed, manufactured, and certified in compliance with ISO 15197:2013. Prior to each test session, the device was checked and calibrated using standard control solutions to ensure the accuracy of the measurements.

2.5. Research products

2.5.1. Components of the test product

Composition: The maize noodle strands were produced entirely from maize kernels through a processing procedure (**Figure 1**).

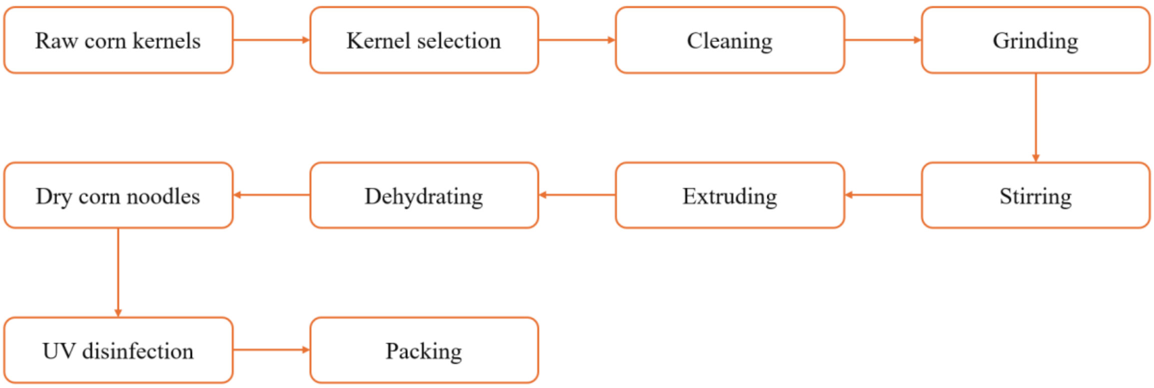

***Figure 1**. Flow diagram of the maize noodle production process*

Nutritional composition: The analytical results of the test sample were obtained at the National Institute for Food Control and are presented in **Table 1**.

***Table 1**. Selected nutritional composition parameters of maize noodles*

No.	Criteria	Unit	Method	Results
1	Potassium content	mg/100g	ICP-OES	55.6
2	Sodium content	mg/100g	ICP-OES	27.2
3	Cholesterol content	mg/100g	GC-MS	< 0.15
4	Gluten content	mg/100g	ELISA	< 0.4
5	Resistant starch content	g/100g	UV-Vis	1.26
6	Carbohydrate content (excluding dietary fiber)	g/100g	AOAC 2020.07	74.5
7	Lipid content	g/100g	Soxhlet	0.92
8	Protein content	g/100g	Kjeldahl	5.70

The test product was prepared according to the manufacturer's instructions to provide 50 g of available carbohydrates. For each volunteer, approximately 67.1 g of maize noodles was added to water at 40 - 50°C and boiled for 5 - 7 min until the noodle strands softened. The cooked noodles were then removed, allowed to cool to an appropriate temperature, and consumed immediately.

2.5.2. Safety criteria quantification

Prior to the intervention, the product was analyzed for quality attributes and safety parameters, including heavy metals (Pb, As, Hg, and Cd) and pathogenic microorganisms (Coliforms, *Escherichia coli*, *Salmonella*, total aerobic microorganisms, total yeasts and molds, and mycotoxins, specifically aflatoxins), by the laboratory of the National Institute for Food Control. The analyses were conducted using standardized methods or validated in-house methods in compliance with the requirements of ISO/IEC 17025. All safety parameters met the current regulatory limits (QCVN 8-1:2011/BYT, QCVN 8-2:2011/BYT, and QCVN 8-3:2011/BYT) and were considered acceptable for inclusion in the study.

2.6. Data processing methods

Only volunteers who completed all test sessions and provided blood samples at all scheduled time points were included in the efficacy evaluation. Screening and analytical results were checked, coded, cleaned, and subjected to basic statistical analysis using Microsoft Excel software. The area under the blood glucose response curve over the 120-minute test period, as well as the GI, was calculated in accordance with the guidelines specified in TCVN 10036:2013 (ISO 26642:2010).

2.7. Research ethics

The study was approved by the Ethics Committee of the National Institute for Food Control. The blood sampling procedure was conducted with adequate preparation of personnel and necessary equipment, including emergency kits, glucose solution, milk, and sweet snacks, to manage potential adverse events such as hypoglycemia, syncope, or other unexpected incidents. During the trial, the health status of the volunteers was monitored by physicians from the Hanoi Five-Star Clinic.

3. RESULTS AND DISCUSSION

In this study, a total of 16 volunteers initially met the selection criteria, participated in the trial, and completed all test sessions. However, data from only 14 volunteers were included in the calculation of the GI of the test product. The results from two volunteers were excluded: one subject exhibited a blood glucose level of < 3.9 mmol/L at 120 min after glucose ingestion, and another subject exhibited a blood glucose level of > 7.0 mmol/L at 120 min after glucose ingestion.

3.1. Characteristics of volunteers

The results presented in **Table 2** indicate that all volunteers participating in the trial were healthy, including six males (42.9%) and eight females (57.1%), with a mean age of 25.6 years and a mean body mass index (BMI) of approximately 22.2, meeting the study eligibility criteria. Data collected during screening confirmed that none of the participants had diabetes mellitus or other chronic diseases, that they maintained healthy dietary habits, and that they were not using any medications during the study period. Clinical cardiovascular examinations and laboratory assessments of liver and renal function parameters were within normal ranges.

Table 2. *General characteristics of the study participants*

Parameter	Mean	SD
Age (years)	25.6	5.4
Body mass index (BMI, kg/m²)	22.2	3.2
Heart rate (beats/min)	77.2	5.40
Systolic blood pressure (mmHg)	115.6	10.7
Diastolic blood pressure (mmHg)	77.8	6.36
Fasting blood glucose (mmol/L)	4.76	0.42
HbA1c (%)	5.01	0.20
Creatinine (µmol/L)	72.3	13.2
AST (U/L)	21.3	5.16
ALT (U/L)	17.4	8.56

3.2. Test results

The study results are presented in **Table 3**, in which blood glucose values are expressed as the mean of 14 volunteers at each sampling time point, together with the standard error of the mean. In this study, measurements were performed in duplicate for the reference food (50 g glucose) and once for the test product.

Table 3. *Results of the reference food and test product trials*

Time (mins)	*Blood glucose (mmol/L) (n = 14)*					
	Glucose test 1		*Glucose test 2*		*Test product*	
	Mean	*SE*	*Mean*	*SE*	*Mean*	*SE*
0	4.76	0.10	4.79	0.11	4.59	0.08
15	7.48	0.27	6.79	0.19	5.34	0.15
30	8.89	0.35	8.17	0.24	6.79	0.18
45	8.52	0.30	8.77	0.28	6.96	0.21
60	7.50	0.27	8.36	0.32	6.24	0.23
90	5.95	0.17	6.82	0.30	5.79	0.20
120	5.51	0.20	5.32	0.21	5.36	0.17
IAUC	268	15.5	287	17.6	159	8.91

The results showed that, following consumption of the reference food, blood glucose levels increased from approximately 4.76 mmol/L at baseline (before intake) to a peak of about 8.89 mmol/L at approximately 30-45 min after intake, and then decreased to approximately 5.32 mmol/L at 120 min. For the test product, the corresponding blood glucose values were 4.59, 6.96, and 5.36 mmol/L, respectively. The detailed changes in blood glucose levels during the test period are illustrated in **Figure 2**.

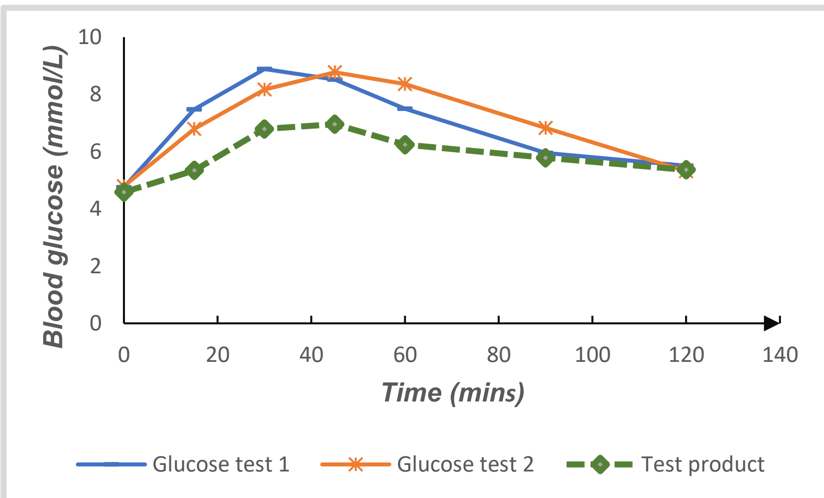

Figure 2*. Blood glucose profiles following consumption of the reference food and the test product*

Compared with the control food, fasting blood glucose levels in all 14 participants were comparable prior to consumption of the test product. However, following intake of the test product, blood glucose increased more gradually and reached a peak at approximately 45 min. Subsequently, glucose levels declined more slowly, reaching 5.36 mmol/L at 120 min, which was equivalent to the value observed for the control food. Changes in blood glucose levels for both the control food and the test product are presented in **Figure 3**. Notably, throughout the monitoring period, blood glucose levels after consumption of the test product did not exceed 7.0 mmol/L, indicating its suitability for individuals requiring glycaemic control.

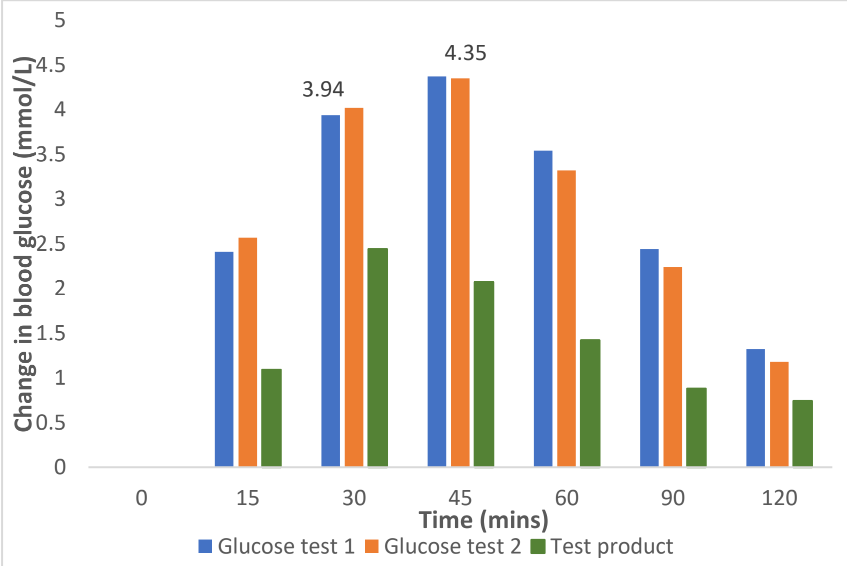

Figure 3. *Blood glucose changes at each test time point*

GI value was determined based on the incremental area under the blood glucose response curve (IAUC) after participants consumed a portion of carbohydrates from the test food on separate occasions and was expressed as a percentage of the mean IAUC obtained for the same amount of carbohydrates from the reference food. It should be noted that determining the final GI value by averaging the IAUC values of the test food across participants and expressing this as a percentage of the mean IAUC of the reference food is not correct. The results of GI measurements obtained in this study are presented in **Table 4.**

Table 4. *Glycaemic index (GI) value of the test product*

Participant	$AUC_{Glucose}$ *(mean)*	$AUC_{Test\ product}$	GI_{Test}*
01	419	208	50
02	249	182	73
03	284	204	72
04	247	140	56
05	256	143	56
06	361	238	66
07	179	108	60
08	200	126	63
09	316	153	48
10	252	135	54
11	248	110	44
12	302	161	53
13	244	170	70
14	326	152	47
Mean ± SE	**277 ± 17**	**159 ± 10**	**58 ± 3**

* *GI values were rounded to the nearest integer*

As shown in **Table 4**, the incremental area under the IAUC, calculated as the mean of two reference tests, ranged from 179 to 419 for the reference food across study participants, while corresponding IAUC values for the test product ranged from 110 to 238. The GI of the test product determined at the individual level varied between 44 and 73, with a mean GI value of 58 ± 3. Although this GI value is higher than those reported in some previous studies [4, 7-8], it remains within the range of GI values documented for several cereal-based foods in published GI tables [9]. Reported GI values for corn and corn-derived products include 65 for yellow corn, 48 for white corn, 49 for sweet corn, 70 for popcorn, 85 for corn starch, 70 for corn flour, 85 for cornflakes, and 68 for corn pasta. These findings underscore the substantial influence of food processing on the glycaemic response and GI of corn and corn-based products.

The nutritional composition analysis of the corn noodle product indicated a high content of available carbohydrates (carbohydrates excluding dietary fiber), reaching 74.5 g/100 g, suggesting that the product can serve as a cereal-based energy source in daily meals. The product was characterized by a low lipid content (0.92 g/100 g) and a moderate protein content (5.70 g/100 g), supporting its suitability for a wide range of consumers. In addition, the resistant starch content was determined to be approximately 1.26 g/100 g. The presence of resistant starch, together with the characteristic starch structure of corn, may partly explain the slower and attenuated postprandial glycaemic response observed following consumption of the test product compared with the reference food (glucose). This moderated glycaemic response prevents excessive postprandial blood glucose excursions. Compared with high-GI foods containing equivalent amounts of carbohydrates, foods with low to medium GI have been shown to significantly reduce postprandial blood glucose levels in healthy adults [1, 4, 6]. These findings suggest that the corn noodle product is compatible with a balanced dietary pattern and may be particularly beneficial for individuals requiring glycaemic control, as such foods do not induce rapid or pronounced increases in postprandial glucose, thereby contributing to the prevention and management of disorders related to impaired glucose metabolism and hyperglycemia-associated complications.

In addition, the compositional analysis of the corn noodle product demonstrated a negligible gluten content (< 0.4 mg/100 g; 4.0 ppm). According to the U.S. Food and Drug Administration (FDA) regulations, foods containing less than 20 ppm of gluten may be labeled as gluten-free. Therefore, the corn noodle product meets the criteria for gluten-free foods and may be suitable for individuals with gluten sensitivity or those requiring a gluten-free diet.

4. CONCLUSION

In this study, GI of the corn noodle product was determined in accordance with TCVN 10036:2013 (ISO 26642:2010). The results demonstrated that the product exhibited a GI value of 58 ± 3, classifying it as a medium-GI food. With this GI profile, the corn noodle product may be considered a suitable component of a balanced diet for individuals requiring glycaemic control, including those with prediabetes, diabetes mellitus, overweight, or obesity. These findings highlight the potential of developing value-added food products from traditional raw materials through appropriate processing techniques to meet current nutritional and public health demands.

The study was conducted in full compliance with ethical standards for biomedical research. Throughout the study period, participants were closely monitored, and no adverse events or safety concerns were observed.

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