FUNCTIONAL BREAKFAST MIXES FOR DIABETES – FORMULATION, CHARACTERIZATION, AND IMPACT OF COOKING METHODS

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Abstract - Changes in lifestyles occurring currently result in bad eating habits. Poor food choices and diets have an impact on the increasing number of generative diseases, especially, diabetes mellitus. It is a rapidly growing health challenge and potential epidemic across low-and-middle-income countries like India. The burden of diabetes is high and increasing globally, mainly fueled by the increasing prevalence of overweight/obesity, unhealthy lifestyles and food habits. So infusion and formulation of low glycemic food mix will help to reduce risk of diabetes mellitus. To formulate the low GI breakfast cereal mix, cereals and pulses with low glycaemic index were selected. The three cereals were mixed with the selected pulse in three different variations to standardize the breakfast cereal mix. Then General breakfast foods were prepared using different cooking methods such as Dry heat, Steaming, and baking method to analyze the impact on the nutritional quality. The study revealed that the red rice, black rice, and foxtail millet with chickpea combination provided complex carbohydrates and a significant amount of soluble and insoluble fibre which helps to lower the glycemic index of the food products by different cooking methods.

Index Terms - Glycemic Index, Impact of cooking methods, Diabetes Mellitus,

INTRODUCTION

Diabetes mellitus is a long-term metabolic condition that is not contagious and is characterized by abnormalities in insulin secretion, action, or both. The metabolism of proteins, fats, and carbohydrates gets messed up when insulin levels are low. Environmental and genetic factors can contribute to the onset of diabetes mellitus. Hyperglycaemia and detrimental alterations in many organs are the end outcomes of a decrease in insulin production, a reduction in glucose consumption, or an increase in gluconeogenesis. (Mainul Haque et al, 2021).

Globally, there were approximately 8 million people with type 1 diabetes in 2021 (95 percent confidence interval: 8-1-8-8), of whom 1 million (18 percent) were under the age of 20, 5 million (64 percent) were between the ages of 20 and 59, and 1 million (19 percent) were 60 years or older. An estimated 35 000 undiagnosed people passed away within a year of the onset of symptoms, and there were 0.5 million new cases diagnosed in that year (median age of onset: 29 years). Eight million (1percent) of those with type 1 diabetes live in low- and lower-middle-income nations. A 10-year-old who was diagnosed with type 1 diabetes in 2021 may expect to live another 13 years on average in low-income nations and 65 years in high-income nations. (Gregory et al., 2021).

When adopting dietary modifications to help avoid diabetes, it's crucial to consider both the quantity and quality of carbohydrate intake. Carbohydrates are converted by the body into tiny sugar molecules, which are then taken into the bloodstream. The pancreas produces insulin, a hormone that facilitates the transfer of sugar from the bloodstream into cells, in response to the consequent increase in blood sugar. Consuming foods high in sugar and refined carbohydrates raises insulin and blood sugar levels, which may eventually cause diabetes. Choosing foods that don't trigger blood sugar rises and limiting overall carbohydrate intake may help lower the risk. (Bashu et al., 2019).

In many randomized controlled trials in people at risk for and with diabetes, systematic reviews and meta-analyses have demonstrated that low GI/GL dietary patterns, which include elements of carbohydrate quality and quantity, lead to lower postprandial glycaemic excursions and improve longer-term glycaemic control and cardiometabolic risk factors. They have also shown that these dietary patterns are associated with a lower incidence of diabetes and cardiovascular disease in prospective cohort studies involving people with diabetes. (Laura Chiavaroli, 2021).

In recent years, refined cereals have increased and even though people want to shift their dietary patterns, it is very hard to find breakfast cereal mix with low GI. Hence, the study aimed to formulate and standardize low GI breakfast cereal mix and analyze the impact of cooking methods on its quality.

MATERIALS AND METHODS

To formulate the low GI breakfast cereal mix, cereals and pulses with low glycaemic index were selected. Black Rice (Oryza sativa L. indica), Red Rice (Oryza punctata), and Foxtail Millet (Setaria italica) from cereals, and Chickpea (Cicer arietinum) under pulses were selected. The ingredients were brought from a hypermarket in Coimbatore as raw ingredients that were processed for further preparation. Before processing, the raw rice and chickpea were cleaned to remove dirt, debris, and impurities. They were soaked and spreaded out on a tray to dry. After drying, the ingredients were grinded into a fine powder and stored in an airtight container for further analysis. To standardize the breakfast cereal mix, the three cereals were mixed with the selected pulse in three different variations.

The following Table -1 presents the different experimental variations of low GI breakfast cereal mix.

Table 1.
Different experimental variations of low GI Breakfast Cereal Mix.

Ingredients (g)	**Variations**		
	A1	**A2**	**A3**
Black Rice Chickpea (BC -A)	70% 30%	75% 25%	80% 20%
Red Rice Chickpea (RC-B)	**B1** 70% 30%	**B2** 75% 25%	**B3** 80% 20%
Foxtail millet Chickpea (FC-C)	**C1** 70% 30%	**C2** 75% 25%	**C3** 80% 20%

The breakfast Cereal mixes were formulated based on the above Table and subjected to Sensory evaluation using a 5-point hedonic scale. Organoleptic analysis was undertaken by the postgraduate students of the Department of Food Science and Nutrition. The sensory attributes such as colour, texture, aroma, appearance, and overall acceptability were evaluated. The mix with the highest score was taken from the three variations for further analysis. Proximate analyses such as Moisture, Ash, Carbohydrates, Protein, Fat, Crude Fibre, Soluble fibre, and Insoluble fibre were analyzed for the chosen variations. pH and water holding capacity were analyzed. pH was analyzed using a digital pH meter to check the acidity or alkalinity of the flour. Water holding capacity refers to the amount of water that flour can absorb and hold without losing its structure. The shelf life of the food mix flour was carried out by keeping the flour at room temperature (25-27°C) for 2 weeks. Common foods were prepared using different cooking methods such as dry heat, steaming, and baking method to analyze the impact on the nutritional quality.

The Result and Discussion of the present study are given below.

RESULTS AND DISCUSSION

1. Sensory Analysis of breakfast mixes

To optimize the ingredients, three variations of breakfast mixes were formulated. They were subjected to sensory evaluation. The ranking given by the panel members was recorded and tabulated.
Table -2 gives the sensory analysis scores of BC mixes.

Table 2.
Sensory Analysis Score of BC Mixes

Product Sample		Color	Texture	Aroma	Appearance	Overall acceptability
BCM	A1	4.32±0.040	4.15±0.043	4.56±0.041	4.712±0.031	4.435±0.0387
	A2	4.72±0.038	4.2±0.051	4.75±0.049	4.751±0.038	4.605±0.044
	A3	4.87±0.0496	4.8±0.066	4.85±0.052	4.925±0.040	4.861±0.0519

Among the three variations, the A3 sample received the highest score and it was taken for further analysis.
The following Table -3 provides the sensory analysis scores of RC mixes.

Table 3.
Sensory Analysis Scores of RC Mixes

Product Sample		Color	Texture	Aroma	Appearance	Overall acceptability
RCM	B1	4.20±0.20	4.36±0.11	4.29±0.10	4.38±0.11	4.307±0.13
	B2	4.28±0.19	4.38±0.13	4.32±0.11	4.40±0.13	4.345±0.14
	B3	4.31±0.23	4.42±0.16	4.35±0.13	4.42±0.15	4.375±0.16

The variation with 20% pulses was accepted by the majority of the panel members and the sample B3 was selected in RC mix for further analysis.
Table -4 depicts the sensory analysis scores of FC mixes.

Table 4.
Sensory Analysis Scores of FC Mix

Product Sample		Color	Texture	Aroma	Appearance	Overall acceptability
FCM	C1	4.31±0.19	4.43±0.28	4.55±0.12	4.32±0.12	4.405±0.17
	C2	4.42±0.19	4.59±0.30	4.59±0.14	4.39±0.13	4.497±0.19
	C3	4.51±0.22	4.61±0.33	4.62±0.16	4.42±0.16	4.541±0.21

Foxtail millet and pulses combination (C3) has received the highest score in overall acceptability. It was chosen for the proximate analysis and food formulation.

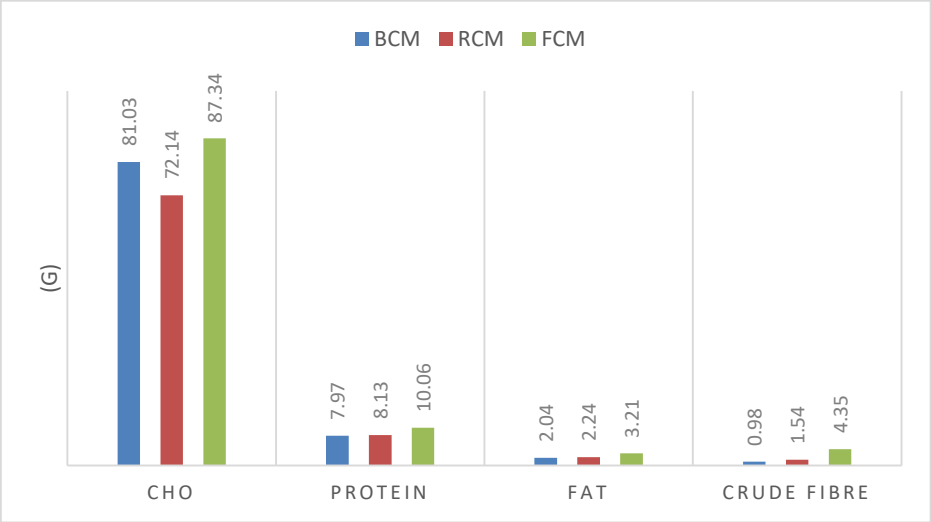
2. Proximate Composition of Breakfast Mix

The proximate analysis of selected food mix flour was done using AOAC. The determination of the proximate composition of the samples includes carbohydrate, protein, crude fibre and fat.
Table – 5 gives the proximate composition of breakfast mixes.

Table 5.
Proximate Composition of Breakfast Food Mixes

BFM	CHO (g)	Protein (g)	Fat (g)	Crude Fibre (g)
BCM (A3)	81.03±0.885	7.97±0.251	2.04±0.040	0.98±0.049
RCM (B3)	72.14±0.280	8.13±0.082	2.24±0.060	1.54±0.041
FCM (C3)	87.34±0.623	10.06±0.130	3.21±0.090	4.35±0.058

The most accepted low glycaemic index breakfast mixes were subjected to proximate composition analysis. Carbohydrates, Protein, Fat, and Crude Fibre were analyzed using standard procedures. The proximate composition of the selected mixes was given in Table -5 and Figure -1.



Proximate Composition of Breakfast Food Mix

Figure-1

The research revealed that the carbohydrate content was more in foxtail millet flour mix when compared to black rice and red rice flour mixes. Foxtail millet and chickpeas are both good sources of complex carbohydrate, and when combined, their carbohydrate content was further increased. The combination of foxtail millet and chickpeas create a synergistic effect that increased the complex carbohydrate content. Because of the low glycaemic index property of foxtail millet, it was good for people with diabetes Mellitus, which helps to lower blood sugar, insulin, cholesterol, and triglycerides. The protein content was also high in the FC mix ie, (10.06 percent), and BCM and RCM have a protein content of 7.97 percent and 8.13 percent. The National Library of Science states that "higher protein intake may reduce the risk of developing diabetes and improve metabolic control" (2019).

The analysis denotes that the value of fat content of the three samples were 2.15g, 2.34g, and 3.44g. This indicates that both the pigmented rice, foxtail millet, and chickpeas were relatively low in fat, so the fat content of the mixture also was low. Which would be suitable for people to reduce the consequences in diabetes mellitus.

The fibre content in black rice, red rice, and foxtail millet was 3.53g, 3.13g, and 4.7g. Crude fibre has the potential to reduce sugar absorption. It was proven in various studies. Journal of Biotica Research Today stated that "dietary Fibre is beneficial to health and, if consumed in adequate amounts, reduces the risk of several chronic diseases, such as cardiovascular diseases, type 2 diabetes, cancers, and weight gain, and also supports digestive health" (Thilagavathi et al., 2020).

About 100g of breakfast mix provided with 8-10g of protein, 72-87g of carbohydrates, 3.5-4.7g of crude fibre, and less than 3.5g of fat. A recent article published in the journal Nutrients in 2021, they observed that increasing fibre intake, particularly insoluble fibre, was associated with improved glycaemic control and insulin sensitivity.

3. Physio-chemical Analysis of Breakfast Mixes.

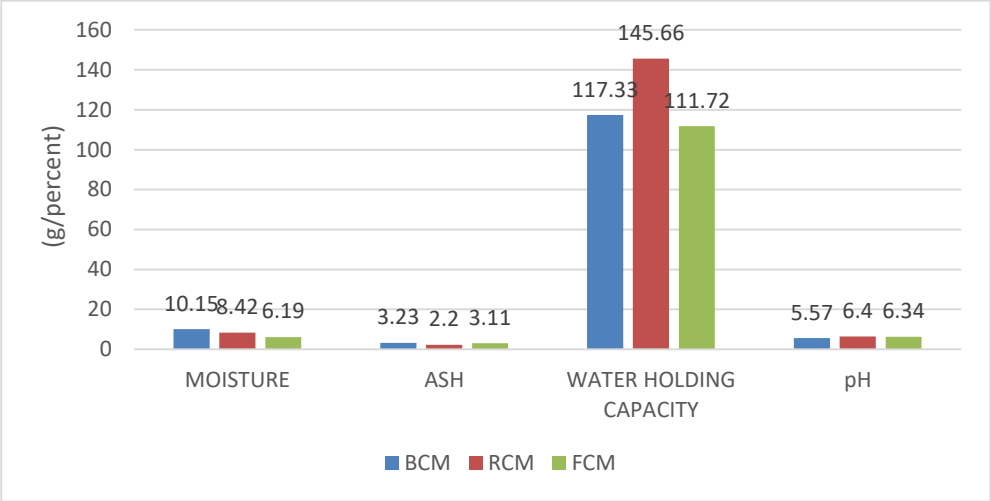
Physiochemical analysis has evaluated the particular chemical properties of test substances, which have been identified as key structural components contributing to penetration, irritation, or sensitization.

Table-6 illustrates the physiochemical properties of the Low GI breakfast mixes.

Table 6.

Physiochemical Properties of Low Glycemic Breakfast Food Mix

Mixes	Moisture (g)	Ash (g)	Water Holding Capacity (%)	pH
BCM (A3)	10.15±0.280	3.23±0.200	117.33±1.763	5.57±0.127
RCM (B3)	8.42±0.257	2.20±0.153	145.66±3.282	6.4±0.195
FCM (C3)	6.19±0.034	3.11±0.102	111.72±1.762	6.34±0.087



Physio- chemical Properties of Breakfast Food Mix

Figure -2

From the table-6 and figure 2, it is clear that the moisture content was low in all the developed mixes which would improve the shelf life of the mixes. Shelf life was one of the most relevant properties of convenience food. The Food Science and Technology journal underscores the "importance of considering shelf life as a critical factor in the production of convenience foods. By understanding and addressing the various factors that can impact shelf life, manufacturers can ensure the safety and quality of their products, improve efficiency and cost-effectiveness, and enhance customer satisfaction" (Arindam Bhattacharya et al., 2021).

The ash content of the mixes was found to be 2.20g to 3.23g. Where the BCM (A3) has more ash content followed by RCM (B3) and FCM (C3).

The water holding capacity and pH were important to determine the dough strength in the preparation of breakfast foods. Higher pH is associated with tougher dough which has been found to be a significant factor impacting dough strength. The journal of Food Sciences found that "a slightly acidic pH (around 5.5) resulted in dough with optimal strength and elasticity, as well as improved product quality and starch digestibility. (Yanyan Li et al., 2021)

The Table-6 shows that water holding capacity of FCM (C3) was low compared to BCM (A3) and RCM (B3). The BCM (A3) has low pH that is slightly acidic (5.57) and other two mixes RCM (B3) and RCM (C3) pH was found to be above 6. Hence, these mixes were having good dough development properties.

4. Microbial Analysis of Breakfast Food Mix

The shelf-life analysis of the food mix flour was carried out by keeping the samples at room temperature (25-27°C) for 4 weeks. It shows that the flour has a good shelf life of about 1 months because of its low moisture content.

5. Soluble Fibre Analysis of formulated products

Soluble fiber is a type of dietary fiber that dissolves in water and forms a gel-like substance in the digestive system. The Journal of Nutrition states that Soluble fibre has been found to be beneficial in reducing the risk of developing type 2 diabetes. Soluble fibre slows down the digestion and absorption of carbohydrates, which helps to regulate blood sugar levels and insulin sensitivity. (Zhu, Y et al., 2021).

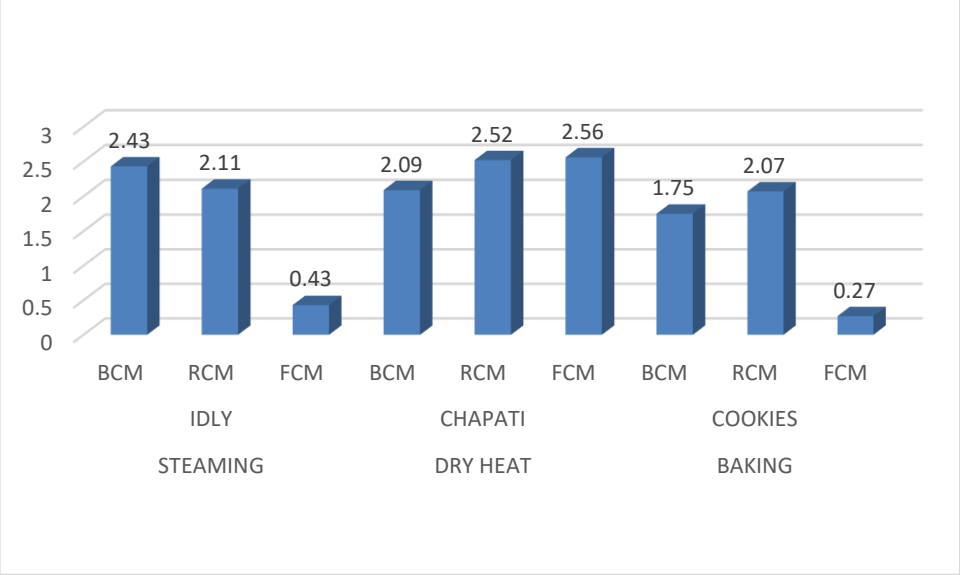
Food products were formulated using three different cooking methods namely steaming, dry heat method and baking to analyse its impact of soluble and insoluble fibre content which have hypoglycemic properties.

The following Table-7 and figure shows the Soluble fibre content of the developed food products.

Table 7.

Soluble Fibre content of the developed products in different cooking methods

Cooking Methods	Products	Ingredients	Soluble Fibre (g)
Steaming	Idly	BCM (A3)	2.43
		RCM (B3)	2.11
		FCM (C3)	0.43
Dry Heat	Chapati	BCM (A3)	2.09
		RCM (B3)	2.52
		FCM (C3)	2.56
Baking	Cookies	BCM (A3)	1.75
		RCM (B3)	2.07
		FCM (C3)	0.27



Soluble Fibre content of the developed products in different cooking methods

Figure-3

The results show that the soluble fiber is high in foxtail millet chapati when compared to other cereal products. Foxtail millet and chickpea mix has a high soluble fiber content due to the individual properties of both ingredients. A recent study published in the Journal of Food Science and Technology found that a combination of foxtail millet and chickpea can provide a high fibre content in the diet. (Jaganathan et al., 2021).

When these two ingredients are combined, they create a mix with an even higher soluble fiber content than either ingredient alone. International Journal of current microbiology and applied sciences states that "consumption of dietary fibre lowers blood glucose levels and helps to maintain normal levels and promote dietary management of type II diabetics. Dietary fiber from millets binds cholesterol and does not allow it to be absorbed, thus protecting from heart diseases" (K. Uma Devi et al., 2019).

Next to foxtail millet chapati, red rice chapati has a high soluble fiber content because it retains the bran and germ layers that were removed during the polishing process in other rices. Red rice was particularly high in soluble fiber, which was concentrated in the outer layer of the rice grain. When red rice and chickpea flour were combined, the resulting mixture has an even higher soluble fiber content. This made it a nutritious and healthy addition to a balanced diet.

These results revealed that the dry heat cooking method retains more amount of soluble fiber content in foods. If the food has high soluble fiber, that has low glycemic index. This is because the soluble fiber slows down the digestion and absorption of carbohydrates, leading to a slower and more gradual release of glucose into the bloodstream. (M.M Hussein et al., 2021)

Therefore, consuming foods that were high in soluble fibre could be an effective strategy to manage blood sugar levels and reduce the risk of developing type 2 diabetes.

6. Insoluble Fibre Analysis of formulated products

Insoluble fiber is a type of dietary fiber that cannot be dissolved in water. It passed through the digestive system relatively intact and is not broken down by the digestive enzymes in the stomach or small intestine. Recent research has showed that insoluble fibre may be particularly beneficial for people with diabetes. One study published in the Journal of Nutrients, found that "consuming a diet high in insoluble fibre was associated with lower blood sugar levels and improved insulin sensitivity in people with type 2 daibetes. (Santhosh Kumar Sukumaran et al., 2020)

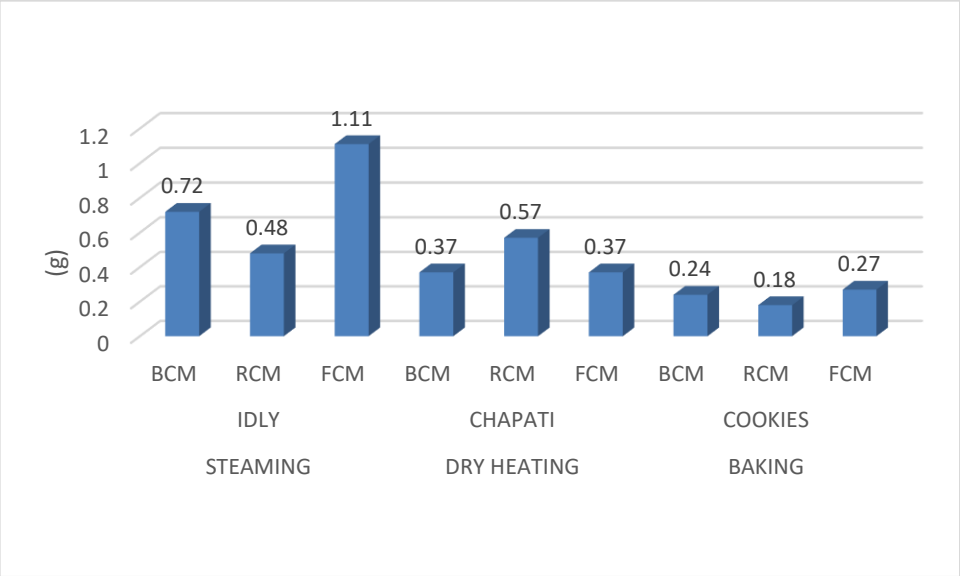
Another study published in the Journal of Nutrition, noticed that "increasing dietary intake of insoluble fibre was associated with a lower risk of developing type 2 diabetes in women. (Zhaoping Li et al., 2021).

The following Table-8 provides the Insoluble fibre content of developed food products in different cooking methods.

Table 8.

Insoluble Fibre content of the developed products in different cooking methods

Cooking Methods	Products	Ingredients	Insoluble Fibre (g)
Steaming	Idly	BCM	0.72
		RCM	0.48
		FCM	1.11
Dry Heat	Chapati	BCM	0.37
		RCM	0.57
		FCM	0.37
Baking	Cookies	BCM	0.24
		RCM	0.18
		FCM	0.27



Insoluble Fibre content of the developed products in different cooking methods

Figure -4

The results showed that insoluble fiber was high in foxtail millet idly because foxtail millet was a whole grain that contains a significant amount of fiber in its outer layer, which was the bran. The bran of the millet grain contains insoluble fiber that did not dissolve in water, which has give the idly a firmer texture and contributed to its bulk. When foods were steamed, they were cooked with hot water vapor, which penetrated the outer layers of the food but did not break them down completely. This means that the insoluble fiber in the outer layers remains intact, resulting in a higher content of insoluble fiber in the cooked food. Hence, foxtail millet idly is a nutritious and healthy choice, especially for those looking to increase their fiber intake.

A recent article published in the International Journal of Food Science and Nutrition titled "Foxtail millet Idli Batter: Nutritional, Textural, and Sensory characteristics, they found that " the foxtail millet idli batter had higher levels of insoluble fibre compared to traditional rice-based idli batter. (Vijayaraghavan et al., 2021).

The results indicated that the baking and dry heat method has low insoluble fiber content because they cause the breakdown of the cell walls in plant- based foods, which contain insoluble fiber due to high temperature. This breakdown can result in a decrease in the overall amount of insoluble fibre present in the food. (Chiemela et al., 2021).

The above results showed that cooking methods has an impact on insoluble fibre content of the food products thereby on the glycaemic index.

CONCLUSION

The study revealed that the red rice, black rice and foxtail millet with chickpea combination provided complex carbohydrates and significant amount of soluble and insoluble fibre which helps to lower the glyceamic index of the food products.The higher temperature and longer cooking time destroyes the fibre content but low temperature cooking for short duration retain high percentage of fibre. Hence, cooking method plays a significant role in the glyceamic index of the food products.

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