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Effect of processing millets on the glycemic index variability and Development of Digital-ready Reckoner for Consumers

T.B Azeez[1*], G. Amuthu. Keerthana[1], M. Aswini[1], V. Kiruthigha[1] and S.U. Subhalakshmi[1]

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ABSTRACT

Purpose: *Millets, as nutri-cereals, offer potential health benefits aiding in the prevention of metabolic disorders like diabetes, obesity, CVD etc. Recognizing their significance, the UN has designated 2023 as the International Year of Millets to enhance global awareness and consumption. To validate their efficacy for individuals with metabolic disorders, the question arises: "Are millets good for individuals suffering from metabolic disorders"*

Research Method: *Millets were purchased from the markets of the Dindigul and Theni districts. This study examines the morphological characteristics, nutrient, phytonutrient composition, and In vitro glycemic index of Finger millet and Kodo millet in unpolished (UP), semi-polished (SP), and polished (P) forms. Furthermore, the study involved standardizing eight dishes using UP millets, calculated their nutrient content and estimated the dietary fibre and In vitro glycemic index. A digital-ready reckoner was developed based on these findings.*

Findings: *The results indicated that the nutrient, phytonutrient composition and In vitro glycemic index were promising in the unpolished Finger and Kodo millet. The estimated GI values of the millet dishes ranged from 29±0.09 to 39±0.17. Standardized dishes made from unpolished ragi and varagu fall under the low glycemic index according to the GI classification.*

Research Limitations: *The result revealed that ratooning of rice can be possible in non-saline soil where available water is present otherwise it's not possible in high-saline soil as well as water deficit areas.*

Practical Value: *The Developed ready reckoner will be of use to the public to create awareness of the differential processing of millets and to understand that the degree of polishing is of utmost importance; otherwise, the bitter truth is millets are also obesogenic.*

Keywords: *Millets, Unpolished, Polished, Semi-polished, Glycemic index, Ready reckoner.*

INTRODUCTION

Millets are among the oldest foods known to humans and they may have been the first cereal grain in use for domestic purposes (Michael Raj and Shanmugam, 2013). They are primarily consumed by disadvantaged communities, they are also known as "raw grains" or "poor man's crops" (Rao *et al.*, 2017). Millet grains are high in fibre, minerals and B-complex vitamins (Bhagavatula *et al.*, 2013). People have started to consume millet, understanding its goodness, especially individuals suffering from metabolic disorders namely diabetes mellitus, CVD and other conditions. They possess anti-diabetic properties and studies have proved that they inhibit the activity of enzymes such as alpha-amylases, alpha-glucosidase, and pancreatic lipase which in turn helps to prevent post-prandial hyperglycemia. Millets are low glycemic food ingredients due to the presence of fibre, polyphenols and flavonoids in the millets (Rotela *et al.*, 2021).

[1]School of Sciences, Department of Home Science, The Gandhigram Rural Institute-(Deemed to be University), Gandhigram-624302, Dindigul, Tamilnadu, India

*thaaze@gmail.com

https://orcid.org/0000-0002-1074-4164

Millets have become increasingly popular as a nutritional and economic supplement to cereal-based food products. India declared 2018 to be the "Year of Millets," and the Food and Agricultural Organization (FAO) also announced 2023 to be the "International Year of Millets." All of these factors contribute to the importance of millet consumption (Verma and Khurana, 2019). Millet-based value-added products hold substantial growth potential for businesses, driven by consumer perception of millet and millet-based foods as they contribute to a healthy lifestyle (Pushpavalli, 2020). Currently, millets undergo various processing methods such as polishing, pearling, or decortications, which are often sold in the market, without clear labelling to distinguish between polished, semi-polished, or unpolished varieties.

With increased milling time, the bran part of millets is removed, resulting in a decrease in head rice production and an increase in broken grain portion. The grains polished for 60 seconds were regarded as fully polished since they had a brighter colour and after another 80 seconds of polishing, the proportion of fractured grains was higher (7.46 per cent). As a result, grains polished for 30 seconds were considered semi-polished (Karakannavar *et al.*, 2021). This processing improves the appearance, cooking quality, and digestibility. Eventually, this damages the grain and leads to nutrient loss, and consumers consume millet that is devoid of the intended benefits. Consumers are not aware of the processing techniques. Almost all households have started to purchase millet for their health benefits in recent times. A large population is consuming millets that no longer provide the intended benefits. The present study was undertaken with the above facts in mind to determine the glycemic index and nutrient content of millets available in the market and to develop a digital-ready reckoner of the millets. This digital ready reckoner comprises information that includes pre-calculated values and helps the consumers to calculate the portion size, nutrient and GI value of standardized millet dishes. Our research aims to raise public awareness regarding the selection of millets and consumption for improved health and well-being.

MATERIALS AND METHODS

Selection and Collection of Millets

The most commonly consumed millets namely finger millet (*Elusine coracana* L.) (FM) and Kodo Millet (*Paspalum scrobiculatum* L.) (KM) were selected for analysis. The Unpolished Finger millet (UPF), Polished Finger millet (PF), Unpolished Kodo millet (UPK) and Semi-polished Kodo millet (SPK) were purchased from the local markets of the Dindigul and Theni districts.

Microscopic examination of selected millets

The morphological features of the UPF, PF, UPK and SPK were examined using a stereo-zoom microscope (Leica EZ4W). This was done to understand the degree of polishing, the colour changes, grain damage, and loss of the bran content.

Processing/preparation of millets for nutrient estimation

Samples of each UPF, PF, UPK and SPK were taken in their raw form and pre-processed by roasting for 6 to 8 minutes until a pleasant aroma arises which is an indicator of roasted millet and soaking for 8 hours. Which are then powdered and used for the estimation of nutrient analysis.

Determination of nutrient, phytonutrient and Elemental mapping

Millet samples were estimated for the proximate composition such as moisture (AOAC, 1990), carbohydrate (Hegde *et al.*, 2005), protein (Lowry *et al.*, 1951), fat (AOAC, 1990), total dietary fibre (AOAC, 1990) and minerals such as calcium (AOAC, 1990) and iron (Raghuramulu *et al.*, 1983) and phytonutrients such as total polyphenols (Sun *et al.*, 2017) and total flavonoid (Zhishen *et al.*, 1999) using the standard methods. The raw millet samples were subjected to elemental mapping using Energy Dispersive Spectroscopic Analysis (EDAX) and were analyzed by using BRUKER Nano, GMmbH, D-12489 (Germany) (Accelerating Voltage - 0 to 30 KeV) instrument.

In vitro Glycemic index testing of the selected millets

In vitro glycemic index was determined according to Goni *et al.*, (1997), reducing sugar (Miller, 1959). A non-linear model established by Goni *et al.*, (1996) was applied to describe the kinetics of starch hydrolysis, Hydrolysis Index (HI) and estimated the Glycemic Index (GI).

Standardization of common South Indian millet dishes

The popular millet dishes namely Ragi chappati, Ragi roti, Ragi kali, Ragi biscuit, Vargu dosa, Varagu upma, Varagu kali and Varagu biscuit prepared using the unpolished finger and kodo millets were standardized. To standardize the selected food items, a written set of procedures was followed for each recipe. Each ingredient was weighed using a weighing scale, before and after preparation, portion size and duration of preparation will be noted in each case. All the dishes were standardized for one serving by the conversion factor method and subjected to sensory evaluation. The nutrients of each dish were computed using the Indian Food Composition Table (2017) (Longvah *et al.*, 2017).

Determination of dietary fibre and GI of the standardized dishes

These dishes were subjected to the determination of total dietary fibre (AOAC, 1990) and the *In vitro* glycemic index using the Goni *et al.*, (1997) method.

Development of digital-ready reckoner

A digital-ready reckoner was developed comprising all the details of identification of unpolished, polished and semi-polished millets, proximate nutrient profile, total polyphenols and total flavonoids along with the dietary fibre content and glycemic index value of the UPF, PF, UPK and SPK were included. The ready reckoner has the dishes by using unpolished finger and kodo millets of the common dishes with portion size, weight, volume and method of preparation along with its computed nutrient and phytonutrient profile (Longvah *et al.*, 2017) and estimated dietary fibre content and glycemic index value. This digital-ready reckoner will help to create awareness for the buyers and consumers of millets.

Statistical analysis

All the investigations were carried out in triplicate and mean±standard deviation was calculated. The data was subjected to an analysis of variance (ANOVA) test and the differences between the means were compared for their significance ($p \leq 0.05$) using SPSS software version 23.

RESULTS AND DISCUSSION

Morphological characteristics of unpolished, polished and semi-polished millets

The morphological aspects of unpolished, polished, and semi-polished Finger millet (FM) and Kodo millet (KM), were investigated under microscopic analysis, the colour changes, grain damage, and loss of the bran content were all evident and are presented in Figure. 01&02. The colour differences between unpolished and polished FM and KM were easily noticeable when examined. The UPF was reddish brownish in colour and glossy, but the PF was pale brown in colour (Figure. 01).

When compared to UPK, the PK samples show the lack of bran and germ, while the SPK samples indicate the absence of bran and a colour that ranges from off-white to white Figure. 02.

Soaked finger and kodo millet were also examined for grain damage, which was seen to increase with the degree of the polishing rate of FM and KM Figure. 01& 02. The microscopic examination of unpolished, polished, and semi-polished finger and kodo millet reveals that the polished and semi-polished millets have more grain, germ and bran damage than the unpolished millets. The loss of bran is a result of the increased degree of polishing observed in microscopic evaluation. All of the unpolished millets had continuous bran and germ components. Many of the market millet samples, on the other hand, were highly polished and pale, with no bran or germ. The lack of germ was indicated by the presence of a characteristic groove in the germ part of the grain (Malavika *et al.*, 2020).

Proximate composition of FM and KM:

The moisture content of FM ranged from 7.23±0.38 to 13.71±0.59 per cent. The moisture content of KM ranged from 09.59±0.43 to 14.50±0.53 per cent. The maximum moisture was detected in the soaked UPF and UPK and the minimum moisture was seen in the roasted PF and SPK. It has been analyzed that the soaking process increases the moisture content and the roasting process decreases the moisture content in both polished and unpolished finger and kodo millet.FM had a carbohydrate content ranging from 65.89±0.58 to 75.97±0.66 g. The carbohydrate content of KM varied from 58.21±0.36 to 67.89±0.64 g. The roasted UPF and UPK had the most carbohydrates, whereas the soaking PF and SPK had the least.

The soaking process alters the complex carbohydrates to simpler forms which might leach out in water during the process. The carbohydrate content of polished and semi-polished millets is lower than that of unpolished millets due to the presence of dietary fibre, as presented in table 01& table 03. Roasting increases the carbohydrate content in both polished and unpolished FM and KM, however soaking decreases

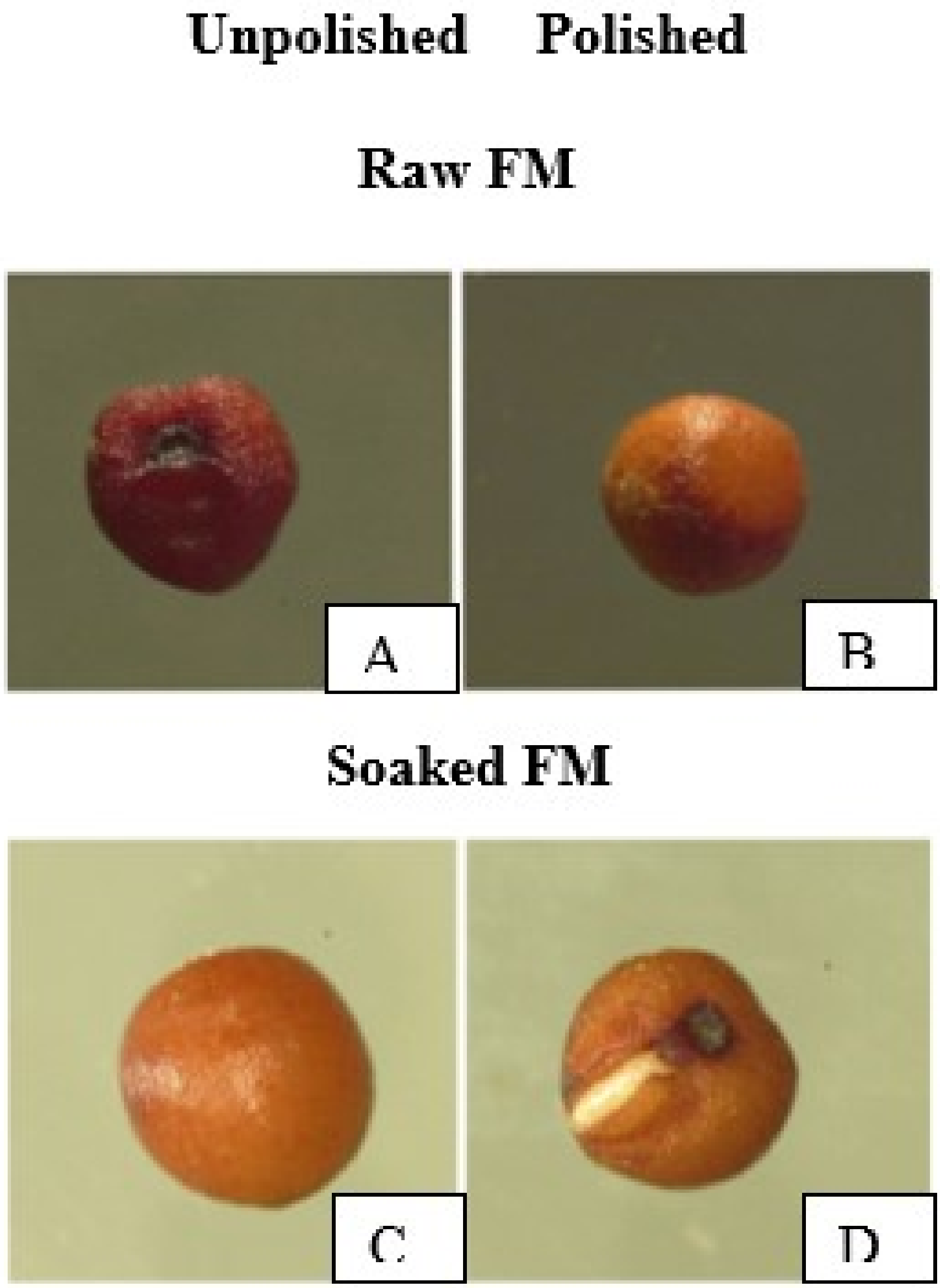

Figure 1: Microscopic images of processed finger millet
A. Unpolished Raw Finger Millet: B. Polished Raw Finger Millet
C. Unpolished Soaked Finger Millet: C. Polished Soaked Finger Millet

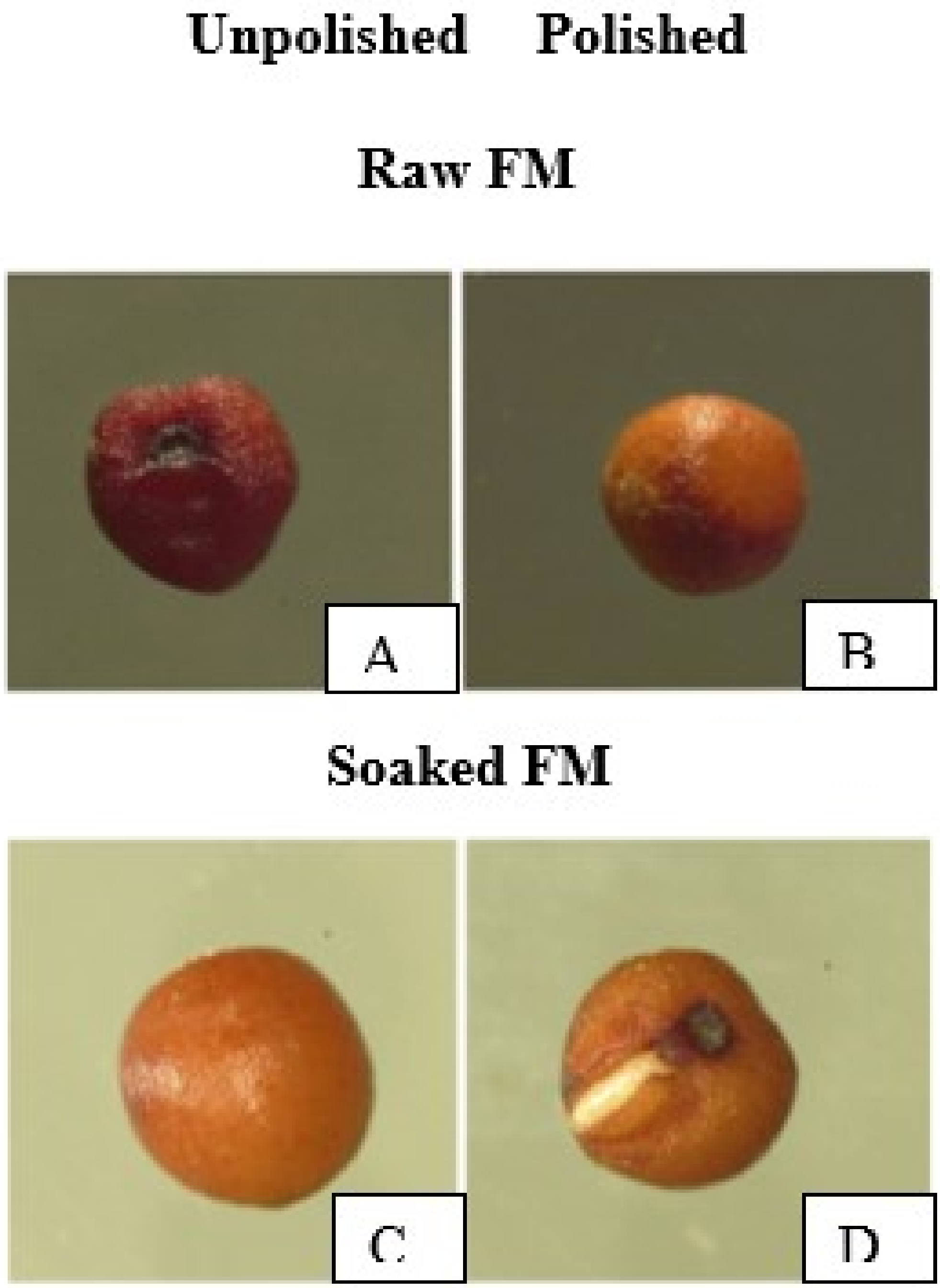

Figure 2: Microscopic images of processed kodo millet
A. Unpolished Raw Kodo Millet: B. Semi-polished Raw Kodo Millet: C. Polished Raw Kodo Millet
D. Unpolished Soaked Kodo Millet: E. Semi-polished Soaked Kodo Millet: F. Polished Soaked Kodo Millet

Table 1: Proximate composition of FM and KM

Process	Millets		Moisture (%)	Carbohydrate (g)	Protein (g)	Fat (g)
Raw	Finger Millet	UPF	10.42±0.58	70.71±0.71	8.23±0.44	1.81±0.18
		PF	9.89±0.47	68.79±0.83	6.12±0.27	1.09±0.02
	Kodo Millet	UPK	12.12±0.16	65.54±0.51	10.02±0.45	2.43±0.07
		SPK	11.94±0.61	61.57±0.49	6.67±0.36	2.13±0.05
Roasted	Finger Millet	UPF	7.91±0.51	75.97±0.66	7.12±0.39	1.57±0.19
		PF	7.23±0.38	71.97±0.30	4.53±0.23	0.98±0.14
	Kodo Millet	UPK	9.61±0.45	67.89±0.64	8.17±0.18	2.07±0.10
		SPK	9.59±0.43	62.77±0.35	5.18±0.12	1.97±0.06
Soaked	Finger Millet	UPF	13.71±0.59	69.14±0.30	9.95±0.37	1.25±0.05
		PF	12.12±0.39	65.89±0.58	5.22±0.21	0.95±0.08
	Kodo Millet	UPK	14.50±0.53	63.19±0.83	12.62±0.17	2.51±0.12
		SPK	13.97±0.67	58.21±0.36	9.18±0.29	2.01±0.28
F Value			0.555	8.172	4.561	28.080
Level of significance			P=0.069	P=0.008*	P=0.038*	P=0.000*

Values reported as Mean±Std Dev.; *Means with superscript indicate they were significantly different at $p \leq 0.05$

Table 2: Calcium, Iron, TPC and TFC content of FM and KM

Process	Millets	Minerals		Phytonutrient	
		Calcium (mg)	Iron (mg)	Total Polyphenol Content (TPC) (mg)	Total Flavonoid Content (TFC) (mg)
Raw	UPF	359.31±0.63	3.97±0.23	145.00±0.87	24.45±0.47
	PF	256.17±0.27	2.88±0.29	88.14±0.39	18.55±0.19
	UPK	17.27±0.21	2.97±0.18	1.98±0.09	76.17±0.21
	SPK	14.81±0.21	1.67±0.16	0.31±0.03	61.12±0.27
Roasted	UPF	321.42±0.49	4.10±0.17	105.06±0.44	17.31±0.30
	PF	252.67±0.36	3.21±0.13	68.12±0.14	16.21±0.14
	UPK	13.15±0.31	3.87±0.22	0.97±0.03	69.34±0.27
	SPK	10.81±0.23	2.56±0.25	0.15±0.03	54.43±0.15
Soaked	UPF	246.76±0.30	2.12±0.16	95.75±0.25	20.86±0.10
	PF	189.41±0.27	1.98±0.06	72.52±0.36	17.62±0.35
	UPK	17.00±0.14	3.00±0.11	1.11±0.04	69.45±0.40
	SPK	14.90±0.19	2.11±0.19	0.11±0.01	56.22±0.11
F Value		58.366	2.008	50.000	208.640
Level of Significance		0.000*	0.192	0.000*	0.000*

Values reported as Mean±Std Dev.; *Means with superscript indicate they were significantly different at $p \leq 0.05$

carbohydrate content. The protein content in FM ranged from 4.53±0.23 to 9.95±0.37 g. The protein content of KM ranged from 5.18±0.12 to 12.62±0.17 g. The protein content of the soaked UPF and UPK was the greatest, whereas the protein content of the roasted PF and SPK was the lowest. The protein content of polished and semi-polished millets is lower than that of unpolished millets. In both polished and unpolished FM and KM, the soaking process enhances protein content whereas roasting reduces protein content. The fat content of FM varied from 0.95±0.08 to 1.81±0.18 g. The maximum fat was found in raw UPF, whereas the lowest fat content was found in roasted PF. KM has a fat content ranging from 1.97±0.06 to 2.51±0.12 g. The soaking UPK had the highest fat content, whereas the roasted SPK had the lowest fat content. Statistically a significant ($p \leq 0.05$) difference in proximate content namely carbohydrate, protein and fat was noticed between Unpolished, Polished and Semi-polished millet varieties as presented in Table 01.

In terms of proximate composition, protein, fat, and fibre contents decreased as the polishing rate or milling time increased, most likely due to the removal of more bran in barnyard millet (Lohani *et al.*, 2012). For each nutrient, an ANOVA analysis revealed a significant ($p \leq 0.05$) effect between moisture and milling time. When milling barnyard millet, the protein content was higher in the outer layers and decreased towards the kernel's centre. For all performed moisture levels, the protein, fat, ash, and carbohydrate values at various milling times (degree of polishing) were significantly ($p \leq 0.05$) different from one another (Lohani *et al.*, 2012). The proximate composition of FM and KM are given in Table 01.

Mineral and Phytonutrient composition:

Calcium levels of FM varied from 189.41±0.27 to 359.31±0.63 mg. KM had a calcium value ranging from 10.81±0.23 to 17.00±0.14 mg. The raw UPF had the highest calcium level, while the soaked PF had the lowest calcium content. Table 2 indicates that there is a significant decrease in the calcium content of polished millets & unpolished millets. The soaking method decreases the calcium content of unpolished, polished and semi-polished FM and KM. The seed coat contains approximately 50% of the calcium content of the whole grain (Chethan and Malleshi, 2007). The iron content of FM ranged from 1.98±0.06 to 4.10±0.17 mg. KM has an iron content ranging from 1.67±0.16 to 3.87±0.22 mg. The maximum iron content was found in roasted UPF and UPK, whereas the lowest iron level was found in soaking UPF and raw UPK. Soaking millet grains in water was shown to lower iron concentration, which might be due to mineral leaching in the soaking water (Yousaf *et al.*, 2021). Soaking the grain fractions in various conditions reduced the iron level considerably ($p = 0.05$) (Jha *et al.*, 2015).

The TPC of FM varied from 68.12±0.14 to 145±0.87 mg. The raw UPF had the highest TPC, while the roasted PF had the lowest TPC. KM has TPC ranging from 0.11±0.01 to 1.98±0.09 mg. **Table 02** indicates that the TPC of polished millet is lower than that of unpolished millet and there is a further reduction of TPC during the roasting and soaking process. The TFC of FM was between 16.21±0.14 to 24.45±0.47 mg. TFC levels in KM ranged from 54.43±0.15 to 76.17±0.21 mg. TFC was greatest in raw UPF and UPK, whereas TFC was lowest in roasted PF and SPK. Table 02 shows that polished millet had a lower TFC than unpolished millet.

ANOVA analysis revealed that there is a significant ($p \leq 0.05$) effect observed between the Unpolished, Polished and Semi-polished millets for the calcium, Total Polyphenol Content (TPC) and Total Flavanoid Content (TFC). Nutrients and phytonutrients are not uniformly spread throughout the grain; the majority of nutrient concentration is higher in the outer part of the grain, so differential polishing or refining results in reduced nutrient content, except starch (Oghbaei and Prakash, 2016).

The dietary fibre content of FM and KM:

The total dietary fibre of the UPF and PF ranges between 7.57±0.20 g and 14.12±0.14 g, while the UPK and SPK vary between 4.89±0.09 g and 8.85±0.14 g Table 03.

It is evident that the dietary fibre content significantly decreases with the degree of polishing rate in both FM and KM. The dietary fibre content of Kodo millet differed significantly between the polished and unpolished varieties at the 1% level of significance (Rajeswari *et al.*, 2021). It has been reported that the dietary fibre content of processed (roasting, soaking, cooking etc.,) cereal and pulses has changed, and the formation of resistant starch can be the cause for the increase in total dietary fibre content (Pushparaj & Urooj, 2011).

Energy Dispersive X-ray Analysis (EDAX):

The energy dispersive spectroscopic analysis showed the presence of different chemical elements on the cell walls of the millets. The order of the chemical

Table 3: Dietary fibre content of FM and KM

Process	Millets	Dietary Fibre (g)		
		Soluble	Insoluble	Total
Raw	UPF	1.68±0.23	12.18±0.45	13.86±0.15
	PF	0.79±0.34	6.78±0.63	7.57±0.20
	UPK	2.73±0.39	5.54±0.28	8.27±0.14
	SPK	1.17±0.41	3.72±0.19	4.89±0.09
Roasted	UPF	1.70±0.25	12.40±0.43	14.10±0.13
	PF	0.87±0.21	6.87±0.36	7.74±0.11
	UPK	2.80±0.31	5.60±0.29	8.40±0.09
	SPK	1.59±0.33	3.88±0.21	5.47±0.07
Soaked	UPF	1.74±0.31	12.38±0.33	14.12±0.14
	PF	0.90±0.43	6.98±0.25	7.88±0.10
	UPK	3.01±0.24	5.84±0.47	8.85±0.14
	SPK	1.87±0.47	3.98±0.39	5.85±0.13
F Value		431.146		
Level of Significance		0.000*		

Values reported as Mean±Std Dev.; *Means with superscript indicate they were significantly different at $p \leq 0.05$

elements of the UPF namely C>O>Ca>Mg>P and K were observed which is represented in the figure. 03. Among these elements, the maximum value of Carbon was detected. However, the chemical elements of the PF present in order of C>O>N>K>Cl>S>Si and Mg were observed, depicted in the figure. 04.

Among these elements, a maximum value of C and a minimum value of Mg were detected. Differential processing of millets removes the minerals in the millets which is evident in the present study as the cell wall of UPF has the calcium, and magnesium content, while in the PF the calcium is absent and a very small quantity of magnesium is present compared to UPF. The order of the chemical elements of the UPK namely C>O>P>Mg>K>Fe and Ca were observed respectively which is represented in the figure. 05. Among these elements, a maximum value of C was detected. But, the chemical elements of the SPK presented in order of C>O>K>P>Cl>S and Mg were observed respectively, as depicted in the figure. 06.

Among these elements, a maximum value of C and a minimum value of Mg were detected. There is an absence of Ca and Fe in the SPK when compared with UPK. The Percentage weight of elements present in UPF, PF, UPK and SPK is represented in table 04.

The study of energy dispersive spectroscopy (EDS) elucidates the numerous constituents within a cell that differ in chemical components, with certain elements being exclusive to certain cell components (Banu &Keishing, 2015).

On comparing the morphological features with this result, it is seen that bran and grain damage was observed in both PF and SPK, which lowers element components present in the cell wall. As a result, it is found that the polished and semi-polished millets have a significant reduction of elements such as Mg, P, Ca, and Fe. This concludes that the removal of bran during polishing may reduce the elements present in it.

Magnesium and phosphorus are both rich in millet. While phosphorus is a crucial part of adenosine triphosphate (ATP), the body's precursor to energy, magnesium has the power to help minimise the effects of migraines and heart attacks. The bran and germ layers of millet, which are abundant in fibre, phytochemicals, and minerals, are removed during milling, which results in a substantial loss (Amadou *et al.*, 2013).

Glycemic Index of FM and KM:

Each millet sample was characterized by the course of starch hydrolysis and has its equilibrium concentration ($C\infty$) and kinetic constant (k) values. White bread used as a reference food, underwent a higher starch hydrolysis during 30-180 minutes when compared with the other samples. The percentage of hydrolysis observed in UPF and UPK was lower than one obtained with PF and SPK during 30-180 minutes. The kinetic constant was lower in UPF (0.077±0.01) and UPK (0.028±0.00). The HI obtained from dividing the AUC of the samples by that of a reference (white bread) was used to determine GI. The HI of UPF, PF, UPK and SPK were 63.59±0.41, 88.50±0.56, 41.25±0.32 and 53.40±0.28 respectively. The *In vitro* estimated GI of

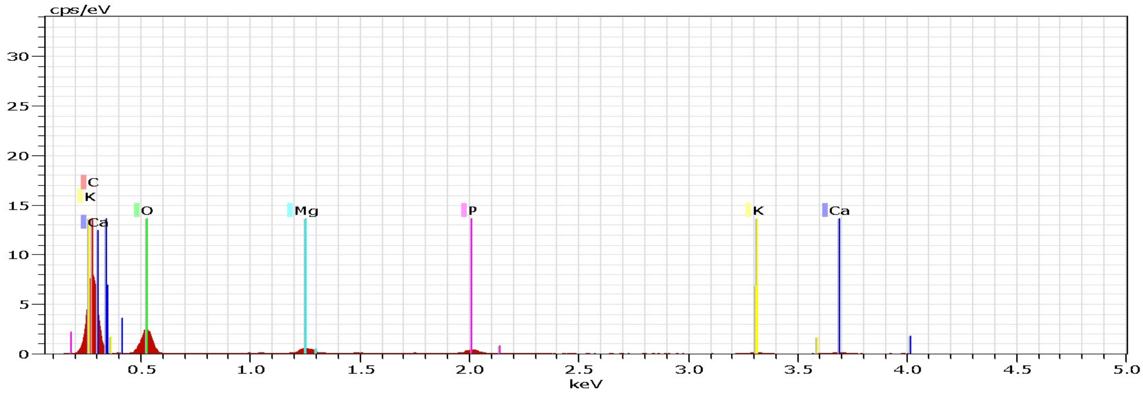

Figure 3: Spectral range of unpolished finger millet

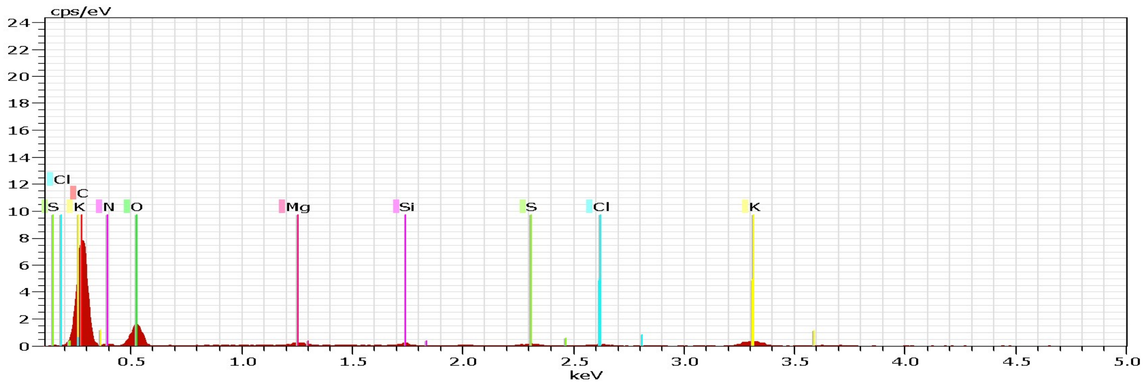

Figure 4: Spectral range of polished finger millet

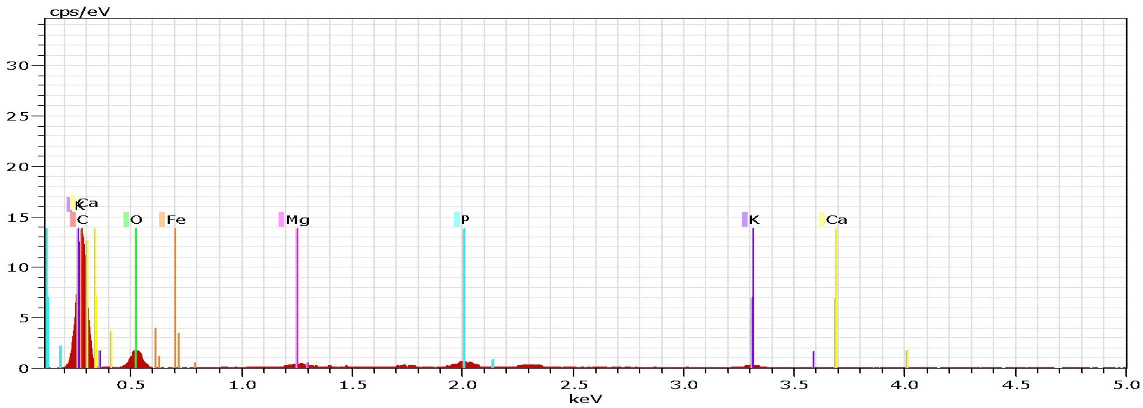

Figure 5: Spectral range of polished finger millet

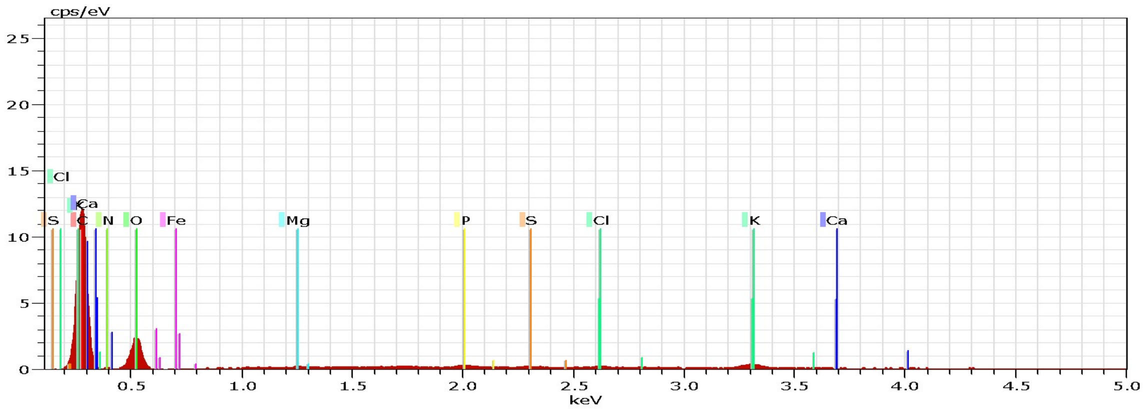

Figure 6: Spectral range of polished finger millet

Table 4: Percentage weight of elements in UPF, PF, UPK and SPK

Samples	Wt. % of Elements (EI)										
	C	N	O	Mg	Si	P	S	Cl	K	Ca	Fe
UPF	57.70	-	32.99	2.25	-	2.10	-	-	1.84	3.12	-
PF	60.66	-	24.28	0.76	0.88	-	1.01	1.01	5.60	-	-
UPK	70.85	5.81	26.87	0.65	-	1.01	-	-	0.50	0.05	0.07
SPK	72.64	-	26.82	0.07	-	0.24	0.09	0.22	0.83	-	-

Carbon (C), Nitrogen (N), Oxygen (O), Magnesium (Mg), Silicon (Si), Phosphorus (P), Sulfur (S), Phosphorus (P), Sulfur (S), Chlorine (Cl), Potassium (K), Calcium (Ca), Iron (Fe)

unpolished finger millet and kodo millet based on HI were 63±0.27 and 44±0.13 respectively. The in vitro GI of polished finger millet and semi-polished kodo millet were 85±0.33 and54±0.21. From the data in Table 05, it is evident that the unpolished millet has a lower GI compared to the polished and semi-polished varieties.

Value-added FM products with a lower GI are potentially beneficial for managing and preventing diabetes and obesity. The quality of dietary fibre, the nature of processing, the ingredients, and the food matrix influence the glycemic response of FM-based products. In terms of glycemic response, whole grains consumed without decortication are a healthier option than minimally polished grains (Shobana *et al.*, 2018). Millet seed coat extract might well interfere with or delay dietary carbohydrate absorption in the small intestine, resulting in a reduction of postprandial blood glucose surges (Shobana, 2009).

Standardization of the common South Indian millet dishes Based on the analysis of the survey(Banu *et al.*, 2023), the dishes of four popular South Indian dishes Unpolished Finger millet and Kodo millet were selected for standardization which includes traditional foods, idli/dosa mix, roti, snacks etc., The standardization of millet dishes includes Ragi chappati, Ragi roti, Ragi kali, Ragi biscuit, Vargu dosa, Varagu upma, Varagu kali and Varagu biscuit. The cooked weight of the different dishes ranges from 30 – 120 gm. In its standard measure, it works out to be 1 to 3 no. and 1 cup. The cooking method includes boiling, sautéing, shallow fat frying, pan roasting, microwave cooking and pressure cooking by using simple types of equipment like Pan, tawa, kadai, pressure cooker and microwave oven. The time taken for the preparation was also standardized and it ranged from 10 to 45 minutes for the unpolished finger millet and kodo millet. A total of 8 items were standardized, presented in table 06.

In the sensory evaluations, table 07 of the dishes showed a mean score of above 8.3 indicating that they are most acceptable.

The nutrient composition table 08 of the standardized dishes is computed using the Food composition table (ICMR-NIN 2017) which is then included in the ready reckoner.

The dietary fibre content was determined for the standardized millet dishes made from UPF and UPK and presented in Table 09.

The total dietary fibre content of the dishes standardized ranged from 2.30±0.14 g to 7.54±0.08 g. The maximum TDF was found in ragi biscuit, whereas the lowest TDF was found in varagu kali.

Glycemic index of the standardized millet dishes

It is understood from the results of the present study that the equilibrium concentrations ranged from 17.23±0.43 to 25.42±0.39 in the standardized FM and KM dishes Table 10.

The kinetic constants (k), which reflected the rate of hydrolysis, ranged between 0.021±0.00 to 0.024±0.00. The kinetic parameters that describe the hydrolytic process of starch digestion were obtained. Equilibrium concentration is reached after 180 minutes of hydrolysis and the kinetic constants indicate the intrinsic susceptibility of the starch in the product to digestion. The differences in kinetic constant values might be due to the rate of enzyme action. The white bread showed higher starch digestibility compared to the standardized millet dishes. The HI, another parameter related to digestibility, is used for the estimation of the GI. The calculated HI values ranged from 24.13±0.24 to 35.73±0.26 in the standardized millet dishes. The estimated GI of the dishes based on the HI ranged from 29±0.09 to 39±0.17. According to the GI classification, High-GI foods are defined as those with a GI value $\geq$70, medium-GI foods are those with a GI from 56 to 69, and low-GI foods are those with a GI value $\leq$55(Atkinson *et al.*, 2021), the standardized dishes can be categorized under the low GI. Low-GI foods

Table 5: Equilibrium concentration, kinetic constant, AUC, calculated HI and estimated GI of UPF, PF, UPK and SPK

Millet variety	C∞	K	AUC	cal HI	eGI	GI classification
UPF	49.19±0.28	0.077±0.01	6740.54±57.17	63.59±0.41	63±0.27*	Medium
PF	57.30±0.71	0.143±0.02	9381.01±73.45	88.50±0.56	85±0.33*	High
UPK	30.08±0.33	0.028±0.00	4372.50±31.56	41.25±0.32	44±0.13*	Low
SPK	41.01±0.25	0.036±0.01	5660.40±44.25	53.40±0.28	54±0.21*	Low

C∞ - Equilibrium concentration, ***k***- Kinetic constant, **AUC** – Area Under Curve, **cal HI**- calculated Hydrolysis Index, **eGI** – estimated Glycemic Index
Values reported as Mean±Std Dev.; *Means with superscript indicate they were significantly different at $p \leq 0.05$

Table 6: Standardized millet dishes

Name of the dishes	Yield	Cooked weights (g)	Preparation Involved	Equipment used	Time taken (min)
Ragi chappati	1 no.	30	Pan roasting	Pan	20
Ragi roti	1 no.	45	Shallow fat frying	Tawa	10
Ragi kali	1 cup	120	Boiling	Pan	10
Ragi biscuit	3 no.	45	Microwave/ Pressure cooking	Microwave oven Pressure cooker	30 45
Varagu dosa	1 no.	50	Shallow fat frying	Tawa	10
Varagu upma	1 cup	75	Sautéing and boiling	Kadai	15
Varagu kali	1 cup	120	Boiling	Pan	10
Varagu biscuit	3 no.	45	Microwave/ Pressure cooking	Microwave oven Pressure cooker	30 45

Table 7: Sensory evaluation of the standardized dishes

Dishes	Appearance	Colour	Flavour	Texture	Taste	Overall Acceptability
Ragi chappathi	8.14±1.70	8.46±0.84	8.54±0.92	8.14±1.33	8.37±0.59	8.35±1.8
Ragi roti	8.44±0.33	8.50±0.35	8.44±0.44	8.40±0.35	8.30±0.67	8.41±0.42
Ragi kali	8.38±1.01	8.67±0.76	8.56±1.57	8.32±0.87	8.64±1.34	8.52±1.53
Ragi biscuit	8.59±0.24	8.60±0.73	8.40±0.54	8.30±0.47	8.55±0.34	8.48±0.46
Varagu dosa	8.51±0.34	8.65±0.45	8.34±0.97	8.45±0.54	8.23±0.98	8.44±0.16
Varagu upma	8.34±0.14	8.65±0.27	8.23±0.66	8.43±0.36	8.23±0.66	8.37±0.41
Varagu kali	8.33±0.46	8.73±0.44	8.26±0.73	8.33±0.73	8.53±0.73	8.36±0.61
Varagu biscuit	8.53±0.68	8.36±0.55	8.33±0.80	8.26±0.58	8.33±0.96	8.63±0.61

Values reported as Mean±Std Dev.

Table 8: Nutritive composition of the standardized dishes computed using the Food composition table (ICMR-NIN 2017)

Dishes	Yield	Cooked wt.	Energy (KCal)	CHO (g)	Protein (g)	Fat (g)	Total dietary fibre (g)			Calcium (mg)	Iron (mg)	Phosphorus (mg)	Total polyphenol (mg)
							Soluble	Insoluble	Total				
Ragi chappathi	1 no.	30	64.15	13.36	1.43	0.38	0.33	1.90	2.24	72.80	0.92	42.00	27.00
Ragi roti	1 no.	45	73.88	14.65	2.11	0.41	0.41	2.22	3.12	136.4	3.50	44.31	30.76
Ragi kali	1 cup	120	160.37	33.41	3.58	0.96	0.84	4.76	5.59	182.00	2.31	105.00	67.50
Ragi biscuit	3 no.	45	146.10	17.94	1.41	7.39	0.29	1.67	1.96	63.58	1.50	41.20	20.60
Varagudosa	1 no.	50	114.54	21.31	4.54	0.87	0.85	1.64	2.64	11.59	1.38	57.10	2.56
Varagu upma	1 cup	75	102.46	20.4	2.78	0.78	0.64	1.33	2.02	5.00	0.70	30.95	0.86
Varagu kali	1 cup	120	165.87	33.1	4.46	1.27	1.06	2.15	3.20	7.64	1.17	50.50	0.27
Varagu biscuit	3 no.	45	147.75	17.85	1.67	7.48	0.36	0.89	1.24	11.27	1.15	24.85	0.43

Table 9: Dietary fibre content of the standardized dishes

Dishes	Dietary fibre (TDF) (g)		
	Soluble	Insoluble	Total
Ragi chappathi	1.98±0.34	4.85±0.41	6.83±0.15
Ragi roti	1.52±0.21	5.28±0.32	6.80±0.16
Ragi kali	1.03±0.45	2.99±0.22	4.29±0.15
Ragi biscuit	1.88±0.31	5.66±0.67	7.54±0.08
Varagu dosa	1.21±0.52	2.28±0.67	3.49±0.35
Varagu upma	1.05±0.32	2.20±0.37	3.25±0.09
Varagu kali	0.57±0.17	1.73±0.82	2.30±0.14
Varagu biscuit	1.16±0.56	2.36±0.48	3.52±0.11

Values reported as Mean±Std Dev.

Table 10: Equilibrium concentration, kinetic constant, AUC, calculated HI and estimated GI of the standardized dishes

Millet dishes	$C\infty$	k	AUC	cal HI	eGI	GI classification
Ragi chappathi	17.23±0.43	0.021±0.00	2557.78±34.98	24.13±0.24	29±0.09*	Low
Ragi Roti	23.04±0.51	0.024±0.00	3434.40±25.67	32.40±0.39	36±0.38*	Low
Ragi Kali	25.42±0.39	0.024±0.00	3787.38±47.17	35.73±0.26	39±0.17*	Low
Ragi biscuit	19.95±0.47	0.022±0.00	2926.66±29.55	27.61±0.19	32±0.16*	Low
Varagu dosa	18.04±0.35	0.021±0.00	2680.74±31.09	25.29±0.41	30±0.13*	Low
Varagu upma	20.11±.26	0.022±0.00	2949.98±46.34	27.83±0.37	32±0.13*	Low
Varagu kali	18.93±0.45	0.021±0.00	2803.70±36.45	26.45±0.51	31±0.09*	Low
Varagu biscuit	19.33±0.53	0.021±0.00	2863.06±30.19	27.01±0.42	31±0.16*	Low

$C\infty$ - Equilibrium concentration, k - Kinetic constant, **AUC** – Area Under Curve, **cal HI** - calculated Hydrolysis Index, **eGI** - estimated Glycemic Index
Values reported as Mean±Std Dev.; *Means with superscript indicate they were significantly different at $p \leq 0.05$

digest slowly, resulting in a slower release of glucose for absorption and a gradual rise in blood glucose with less demand on the pancreas to secrete insulin(Esfahani *et al.*, 2009; Shobana *et al.*, 2017). Aside from the complex molecular makeup of millet starch, the nature of millet processing and also the type of food play an important role in the glycemic response of millet foods. Food-grade phenolic inhibitors derived from millet seed coat extracts might well be preferable options for inhibiting carbohydrate breakdown and controlling the glycemic index of food products(Shobana *et al.*, 2009).

Digital-ready reckoner

A digital-ready reckoner was developed in the online platform of canva.com and it comprises all the details of identification of unpolished, polished and semi-polished millets, proximate nutrient profile, total polyphenols and total flavonoids along with the dietary fibre content and glycemic index of the UPF, PF, UPK and SPK were included. The ready reckoner has the dishes by using unpolished finger and kodo millets of the common dishes with the method of preparation along with its computed nutrient and phytonutrient profile (ICMR-NIN 2017) and estimated dietary fibre content and glycemic index value. This digital-ready reckoner will help to create awareness for the buyers and consumers of millets. The link for the digital-ready reckoner is https://bit.ly/39ixoQ7. The major nutrients of each recipe can be calculated using the nutritive calculator which has been prepared using computation (ICMR-2017) and the link for the nutritive calculator prepared using an Excel sheet is https://bit.ly/3EIjRhG.

CONCLUSION

The study results showed that the polished finger millet and semi-polished kodo millet had lower nutrient, and dietary fibre content, which could be attributed to the loss of bran content, whereas unpolished millets are excellent source of phytonutrients and had a lower glycemic index compared to the polished and semi-polished one. The dishes prepared using unpolished millet also serve as a low GI. The survey unveils the truth that the consumers are unaware that the millets that they buy are processed and they are consuming the millets with less nutritional and functional benefits(Banu *et al.*, 2023), it is concluded that unpolished millets are not available in supermarkets or local grocery stores and only a few shops in the market sell them. Consuming unpolished millet will aid us in achieving good health and well-being. Polishing the millet truly reduces the mineral and fibre content and people prefer to consume millet for the claim that it has fibre and minerals thus it makes no difference with rice. As a result, public education must focus on the dietary choices in selecting the millets, otherwise, it will create an obesogenic environment even after consuming millets as a choice for a healthy lifestyle.

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Availability of data: All data are available from the corresponding author upon reasonable request.

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