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# *In vitro* starch digestibility and *in vivo* glucose response of minor tuber-based vermicelli & *upma*

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After grains and legumes, minor tubers are the third most significant food crop, and they have vital nutritional and nutraceutical qualities that offer additional health benefits in addition to fullness. A study was conducted to develop minor tuber-based vermicelli and to evaluate its *upma*. Five different minor tubers were selected and processed to flour and used for development of vermicelli with replacement of refined wheat flour and further to *upma*. Results indicated that100% replacement had higher acceptability index (92.24%) compared to control. Lesser Yam vermicelli *upma* had higher acceptability scores for all sensory parameters. Energy, protein, fiber, calcium, iron and vitamin A contents of vermicelli *upma* were lower than tuber vermicelli. Further, when compared to wheat vermicelli upma, Lesser Yam vermicelli *upma* had low glycemic index (52.34). Hence, the refined wheat flour can be replaced with tuber flour in vermicelli.

**Keywords**: *In vivo* glucose response, *In vitro* starch digestibility, Minor tuber flour, Nutritive value, Sensory properties, Vermicelli

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In relation to human existence, survival, and socioeconomic history, roots and tubers were essential components of the diet during the early stages of human evolution and the most significant food crops with a very old origin in the tropics and subtropics[1]. The third most significant crop for human sustenance after cereals and legumes, minor tuber crops are the most underutilised and provide either a staple or supplementary food for nearly one-fifth of the world's population. Only a small portion of the population consumes the tubers, making them underutilised crops.

They contribute about six percent of the world's dietary calories and are reservoirs of resistant starch, minerals, vitamins, antioxidants and dietary fiber. In addition, these tubers are also used in indigenous medicine to cure various diseases viz., ulcers, jaundice, vomiting, piles, epilepsy, diarrhoea, headache, rheumatism, leprosy and dysentery besides being rich in nutritional and nutraceutical properties and adding variety to the diet[2-4].

Traditional foods like vermicelli are the expression of our Indian culture, history and lifestyle. Vermicelli can be used in many different forms for making various sweets and savoury products. So, an attempt was made to prepare most commonly used products like Vermicelli *upma*, also known as *semiya upma* a popular South Indian breakfast. Hence replacing major ingredients in the preparation of vermicelli *upma* with minor tubers not only adds variety to diet but also enhances the nutritional and nutraceutical properties of the Vermicelli *upma*, which may help to prevent non-communicable diseases and provides a means of utilisation of tubers by farmers. Further, since tubers are permitted culturally during fasting, the vermicelli prepared with tubers can be used as food for fasting, being rich in dietary fiber (REF), it provides satiety and sustainability for longer duration. Hence, the current study was commenced with an objective to develop minor tuber-based vermicelli and to study its glycemic index in the form of *upma*.

## Materials and Methods

### Procurement and processing of minor tubers

The minor tubers *viz*., colocasia banda type (*Colocasia esculenta*), tannia bulbs (*Xanthosoma sagittifolium*), lesser yam (*Dioscorea esculenta*), lion foot yam (*Amorphophallus paeoniifolius*) and

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(*Dioscorea villosa*) wild edible yam were procured from the farmers of Joida taluk, Uttar Kannada district. Tubers were washed, cleaned, peeled and blanched in hot water containing 2% of citric acid to prevent enzymatic browning and cut into slices and dried in the cabinet drier at 40±2°C till constant weight was attained. The dried chips were powdered in a flour mill and flour was passed through 300 µ mesh, packed in polyethylene pouches and stored in air tight container at ambient temperature for further use.

**Development of vermicelli with minor tubers**

Vermicelli was prepared using single screw extruder replacing refined wheat flour with tuber flour in different proportions (50, 60, 70, 80, 90 and 100%). Prepared tuber vermicelli was cooked in water and subjected to sensory evaluation. Most accepted level was employed for incorporation of different tubers. The vermicelli prepared with 100% refined wheat flour was used as control for comparison. The vermicelli was made into *upma* by employing traditional method i.e., roasting, cooking the vermicelli and seasoning with other ingredients.

**Sensory evaluation of developed products**

The organoleptic evaluation was conducted using 9-point hedonic scale by 15 trained of judges. The panel members were instructed to evaluate the products individually. Most accepted ratio of refined wheat flour and tuber flour was further employed to test suitability of five selected tuber flours in the preparation of vermicelli and in-turn to *upma*. Vermicelli upma was subjected to organoleptic evaluation.

**Nutrient composition of tuber vermicelli and upma**

The nutrient composition of tuber vermicelli and its upma was computed using Annapurna software (designed by Dr. M. R Chandrasekhar, Bangalore), to include proximate composition, minerals and vitamins.

***In vitro* starch digestibility (IVSD)**

IVSD of the vermicelli upma was analyzed by adopting the method by Mouliswar *et al*.[5]. Pancreatin and amyloglucosidase were the enzymes used for starch digestibility.

**Prediction of glycemic index (PGI) by *in vitro* method**

To predict the glycemic index, the starch digestibility at 90 min was considered. PGI was calculated using the equation[6].

$$PGI = 39.21 + 0.803\ (HI_{90})$$

**Estimation of glycemic index of tuber vermicelli *upma* by *in vivo* method**

Twenty-five healthy adult subjects aged between 30 and 45 years were registered for the study. The willingness in the form of written consent was obtained in prescribed format, from all the volunteers after detailed explanation of methods and objectives of the study. Permission to conduct the study was obtained from the Institutional Research Ethical Committee (IREC).

**Standard and test foods**

Glucose (50 g) was given as standard while wheat vermicelli upma was employed as control food and tuber vermicelli *upma* was the test food. The subjects were given standard glucose (50 g), control food and test food to provide 50 g of available carbohydrate.

**Blood glucose response**

*In vivo* estimation of glycemic index of selected food product was carried out by selecting 25 non-diabetic volunteers. The subjects were instructed to be fasting for at least 12 h prior to the experiment. The volunteers were fed with glucose (50 g) after recording fasting blood glucose level by finger prick method using Dr. Morphene glucometer. After a gap of one week, control food (wheat vermicelli upma) to provide 50 g available carbohydrate was fed. Similarly, after one week of wash out period, test food (tuber vermicelli upma) was given. The subjects were instructed to consume the food within 10 min. Blood glucose level was recorded after the feeding session, every 30 min up to 120 min. Area Under Curve (AUC) was calculated using the trapezoidal rule. The glycemic index (GI) was calculated based on the glucose response using the following formula;

The graph was plotted and GI was calculated using formula

$$GI = \frac{Area\ under\ food\ curve}{Area\ under\ GTT\ curve} \times 100$$

**Statistical analysis**

Statistical analysis of the findings (one-way analysis of variance and F test) was performed using SPSS software.

## Results and Discussion

**Development of vermicelli with minor tubers**

Vermicelli is a primeval traditional pasta in India, which could be stored for longer period and can be

converted in to varieties of delicious foods like vermicelli kheer, *upma*, cutlet, *vada* and many more. Vermicelli is more often a convenience food. Hence an attempt was made to replace refined wheat flour with tuber flour.

**Optimization of level of incorporation of tuber flour**

Lion foot yam flour was incorporated at different levels to develop vermicelli. Mean sensory scores obtained for cooked tuber vermicelli are presented in Table 1. With increase in tuber flour, the flavor, taste, texture and overall acceptability scores increased, whereas appearance and color scores decreased from 8.26 & 8.33 (at 50%) to 7.33 & 7.26 (at 100%), respectively. At 100% incorporation, flavor, taste, texture and overall acceptability were liked very much with scores of 8.73, 8.66, 8.53 and 8.80 respectively. This resulted in raise in acceptability indices from 81.94 at 50% incorporation to 92.24 at 100% incorporation level, which was highly acceptable when compared to control. Hence 100% tuber flour was continued for further study.

**Development of vermicelli with different tubers**

***Physical and functional characteristics of vermicelli with different tubers***

Physical and functional characteristics of vermicelli are described in Table 2. Water requirement for dough preparation varied from 110 – 190 mL. However, control vermicelli (110 mL) required less water than tuber vermicelli. Mixing flour was found to be easy with control and tannia bulbs. The vermicelli strands varied in colour, texture and taste. Control was found to be creamy white in colour which was opaque and had hard texture, couldn't break easily and had bland taste. Similar characteristics were reported in lesser

Table 1 — Optimisation of level of tuber flour in wheat vermicelli

| Level of incorporation (WF:TF) | Appearance | Colour | Flavour | Taste | Texture | OAA | AI |
|---|---|---|---|---|---|---|---|
| 100:0 | $8.40\pm0.50^{a}$ | $8.46\pm0.51^{a}$ | $7.26\pm0.45^{c}$ | $7.53\pm0.51^{c}$ | $7.60\pm0.50^{b}$ | $7.73\pm0.45^{cd}$ | 87.00 |
| 50 : 50 | $8.26\pm0.45^{a}$ | $8.33\pm0.48^{a}$ | $6.00\pm0.00^{e}$ | $7.33\pm0.48^{cd}$ | $7.20\pm0.41^{c}$ | $7.13\pm0.35^{f}$ | 81.94 |
| 40 : 60 | $8.06\pm0.25^{ab}$ | $8.20\pm0.41^{ab}$ | $6.46\pm0.51^{d}$ | $7.06\pm0.25^{d}$ | $7.46\pm0.51^{bc}$ | $7.26\pm0.45^{ef}$ | 82.40 |
| 30 : 70 | $7.80\pm0.41^{bc}$ | $7.93\pm0.25^{b}$ | $7.06\pm0.25^{c}$ | $7.60\pm0.50^{c}$ | $7.60\pm0.50^{b}$ | $7.53\pm0.51^{de}$ | 84.29 |
| 20 : 80 | $7.66\pm0.48^{cd}$ | $7.60\pm0.50^{c}$ | $7.33\pm0.48^{c}$ | $7.93\pm0.25^{b}$ | $7.73\pm0.45^{b}$ | $8.00\pm0.00^{c}$ | 85.64 |
| 10 : 90 | $7.53\pm0.51^{cd}$ | $7.46\pm0.51^{c}$ | $7.80\pm0.41^{b}$ | $8.40\pm0.50^{a}$ | $8.33\pm0.48^{a}$ | $8.46\pm0.51^{b}$ | 88.85 |
| 0 : 100 | $7.33\pm0.48^{d}$ | $7.26\pm0.45^{c}$ | $8.73\pm0.45^{a}$ | $8.66\pm0.48^{a}$ | $8.53\pm0.51^{a}$ | $8.80\pm0.41^{a}$ | 92.24 |
| F value | 11.17 | 15.15 | 71.07 | 25.10 | 14.44 | 31.88 | |
| SEM | 0.11 | 0.11 | 0.10 | 0.11 | 0.12 | 0.10 | |
| CD | 0.32** | 0.33** | 0.29** | 0.32** | 0.35** | 0.30** | |

Note: TF- Tuber flour, WF-Wheat flour, C – Control, WET- Wild edible type, TB- Tannia bulbs, COC- Colocasia (banda type), LFY-lion foot type, LY - Lesser yam, OAA-Overall acceptability, AI- Acceptability Index, ** Highly significant @ 1%. Average of 15 judges. Means with same superscript do not differ significantly.

Table 2 — Physical and functional characteristics of *vermicelli* with different tubers

| Characteristics | Control | Colocasia banda type | Lion foot yam | Wild edible type | Tannia bulbs | Lesser yam |
|---|---|---|---|---|---|---|
| | | | Characteristics of Dough | | | |
| Water required (mL) | 110 | 181 | 180 | 190 | 184 | 187 |
| Kneading (mixing behaviour) | Easy | Easy but higher lump formation | Difficult | Slightly difficult | Easy | Slightly difficult (sticky) |
| | | | Characteristics of Vermicelli | | | |
| Water required for cooking (mL) | 150 | 120 | 120 | 95 | 115 | 110 |
| Strand colour | Creamy white and opaque | Light brown and opaque | Light brown & opaque | Brown and opaque | Creamy and opaque | Creamy Yellow and transparent |
| Strand texture | Hard | Slightly hard | Slightly hard | Less hard | Hard | Hard and firm |
| Strand breakability | Difficult to break | Slightly breakable | Slightly breakable | Easy to break | Difficult to break | Difficult to break |
| Taste | Bland | Good taste with slight acridity | Grainy feel | Slight grainy feel | Good taste | Pleasant flavour and taste |

yam vermicelli with creamy yellow and translucent; had hard and firm texture with pleasant flavour. On the other hand, wild edible yam vermicelli strand was opaque with brown colour, which was easily breakable. It may be due to variation in content and type of starch in different tubers. Decreased appearance and colour, was perhaps due to high phenol content of minor tubers[7] and enzymatic browning. However, while cooking, control vermicelli absorbed more water (150 mL) than tuber vermicelli. Among all tuber vermicelli, colocasia and lion foot yam vermicelli absorbed more water (120 mL). Boiled vermicelli of lesser yam and tannia bulbs had acceptable taste, while that of wild edible type and lion foot yam had grainy feel. It may be due to variation in content and type of starch in different tubers. The water absorption capacity of the flour affects textural scores. Decreased appearance and colour was perhaps due to high phenol content of minor tubers[7] and enzymatic browning.

***Sensory scores of vermicelli upma with different tubers***

Sensory evaluation results of vermicelli *upma* of different tubers are presented in Table 3. Highly significant differences were observed in sensory parameters of vermicelli *upma* prepared with different tubers. The vermicelli upma prepared with 'Lesser yam' (LY) received higher scores for all sensory parameters with acceptability index of 96.50. Appearance and colour of LY vermicelli upma was on par with control while, other parameters were scored higher than control. This can be reasoned to composition of flavonoids and phenols present in tuber, which differ from that of wheat[8]. However, Wild edible type and Colocasia were less suitable for vermicelli preparation.

**Nutritive value of vermicelli with different tubers and vermicelli *upma***

A wide variation in nutrient content was observed and is depicted in Table 4. Energy content was significantly higher in lion foot yam vermicelli and *upma* (375 & 320 kcal) followed by lesser yam and wild edible yam (372 & 318 kcal). Maximum amount of protein (10.90 & 5.63) and fat (0.99 & 14.20) in vermicelli & *upma*, respectively, were recorded in control compared to tuber vermicelli and *upma.* While Colocasia tuber vermicelli and *upma* had numerically high amounts of fiber (9.60 & 6.02) and carbohydrate (83.50 & 44.30), the wheat vermicelli and *upma* had lower amounts. Whereas calcium, phosphorus & zinc were higher in colocasia tuber vermicelli and *upma* (1035 & 629.09; 398.70 & 309.45; 6.90 & 3.45 mg/100 g respectively) when compared to control (22.80 & 35.45; 119.80 & 73.45; 0.60 & 0.36 mg/100 g respectively). Iron content was maximum (4.30 & 3.90 mg/100 g) in tannia bulbs vermicelli and *upma* followed by Colocasia vermicelli and *upma* (3.80 & 3.18 mg/100 g). However, sodium content was higher in control vermicelli and upma (1997 & 2153 mg/100 g). The potassium and copper contents were higher in lesser yam vermicelli and *upma* (989.10 & 2051.45; 1024 & 1033 mg/100 g, respectively).

Wild edible yam vermicelli and upma had maximum amount of vitamin A, β carotene, thiamine and riboflavin (78 & 161.15; 565 & 769.09; 0.90 & 0.18; 1.50 & 0.18 mg/100 g, respectively) compared to control vermicelli and *upma* (2.10; 26.72, 15.0; 50.45, 0; 0.10 & 0.10; 0.02, respectively). Niacin content was higher in lesser yam vermicelli (2.70 mg) and upma (0.56 mg) while lower value was found in control vermicelli (0.38 mg) and *upma* (0.01 mg).

Energy, carbohydrate, fiber, vitamins and minerals content was higher in tuber vermicelli *upma* than

Table 3 — Sensory scores of vermicelli *upma* with different tubers

| Tubers | Appearance | Colour | Flavour | Taste | Texture | Overall acceptability | AI |
|---|---|---|---|---|---|---|---|
| Control | 8.73±0.45$^{a}$ | 8.75±0.45$^{a}$ | 7.80±0.41$^{b}$ | 7.53±0.51$^{c}$ | 8.00±0.00$^{b}$ | 8.00±0.00$^{b}$ | 90.35 |
| COC | 6.33±0.48$^{d}$ | 6.20±0.41$^{d}$ | 7.26±0.45$^{c}$ | 7.60±0.50$^{c}$ | 7.66±0.61$^{bc}$ | 7.33±0.48$^{c}$ | 78.35 |
| LFY | 7.00±0.00$^{c}$ | 7.13±0.35$^{c}$ | 8.00±0.75$^{b}$ | 8.13±0.51$^{b}$ | 7.40±0.91$^{c}$ | 7.06±0.25$^{d}$ | 82.81 |
| WET | 6.26±0.45$^{d}$ | 6.13±0.35$^{d}$ | 8.06±0.45$^{b}$ | 8.20±0.67$^{b}$ | 6.26±0.45$^{d}$ | 6.86±0.35$^{d}$ | 77.35 |
| TB | 7.80±0.56$^{b}$ | 7.60±0.50$^{b}$ | 8.00±0.65$^{b}$ | 8.20±0.56$^{b}$ | 8.00±0.53$^{b}$ | 8.00±0.37$^{b}$ | 88.14 |
| LY | 8.53±0.51$^{a}$ | 8.46±0.51$^{a}$ | 8.80±0.41$^{a}$ | 8.86±0.35$^{a}$ | 8.86±0.35$^{a}$ | 8.80±0.41$^{a}$ | 96.50 |
| F value | 84.21 | 94.78 | 12.47 | 12.59 | 36.29 | 63.41 | |
| SEM | 0.11 | 0.11 | 0.14 | 0.13 | 0.14 | 0.09 | |
| CD | 0.32** | 0.31** | 0.39** | 0.38** | 0.40** | 0.25** | |

Note: WET- Wild edible type, TB- Tannia bulbs, COC- Colocasia (banda type), LFY-lion foot type, LY - Lesser yam, AI- Acceptability Index,** Highly significant @ 1%. Average of 15 judges. Means with same superscript do not differ significantly.

Table 4 — Nutrient composition of vermicelli and *upma* of different tubers

| Nutrients | Control | | Colocasia banda type | | Lion foot yam | | Wild edible type | | Tannia bulbs | | Lesser yam | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | VC | UM | VC | UM | VC | UM | VC | UM | VC | UM | VC | UM |
| | | | | | | Proximate principles (g/100 g) | | | | | | |
| Energy (Kcal) | 306 | 309 | 364 | 314 | 375 | 320 | 372 | 318 | 359 | 311 | 372 | 318 |
| Protein | 10.90 | 5.63 | 4.40 | 2.72 | 7.20 | 4.07 | 7.10 | 4.08 | 4.10 | 2.90 | 8.10 | 4.18 |
| Fat | 0.99 | 14.20 | 0.40 | 13.90 | 0.32 | 13.87 | 0.25 | 13.83 | 0.32 | 13.87 | 0.22 | 13.83 |
| CHO | 73.30 | 39.27 | 83.50 | 44.36 | 83.40 | 45.06 | 82.90 | 44.00 | 82.10 | 43.63 | 83.10 | 44.18 |
| Fiber | 3.00 | 2.18 | 9.60 | 6.02 | 7.80 | 4.54 | 9.40 | 5.27 | 8.80 | 4.90 | 7.60 | 4.36 |
| | | | | | | Minerals (mg/100 g) | | | | | | |
| Calcium | 22.80 | 35.45 | 1035.00 | 629.09 | 599.00 | 416.54 | 646.50 | 439.63 | 694.50 | 463.09 | 447.00 | 342.36 |
| Phosphorus | 119.80 | 73.45 | 398.70 | 309.45 | 147.60 | 187.09 | 162.40 | 194.36 | 156.10 | 191.27 | 199.10 | 212.18 |
| Iron | 0.70 | 0.63 | 3.80 | 3.81 | 1.80 | 2.72 | 2.00 | 2.90 | 4.30 | 3.90 | 2.50 | 2.09 |
| Sodium | 1997.0 | 2153.27 | 809.00 | 1963.65 | 809.10 | 1963.81 | 804.90 | 1961.63 | 811.00 | 1964.72 | 989.10 | 2051.45 |
| Potassium | 128.70 | 63.09 | 550.00 | 315.09 | 33.10 | 109.63 | 250.00 | 168.90 | 591.00 | 335.09 | 1024.00 | 1033.81 |
| Copper | 0 | 0 | 0.20 | 1.18 | 0.20 | 0.18 | 0.20 | 0.19 | 0.20 | 0.16 | 7.90 | 3.81 |
| Zinc | 0.60 | 0.36 | 6.90 | 3.45 | 1.10 | 1.72 | 1.00 | 1.54 | 1.20 | 1.72 | 2.10 | 2.09 |
| | | | | | | Vitamins | | | | | | |
| Vitamin A (µg) | 2.10 | 26.72 | 7.80 | 123.45 | 41.40 | 143.63 | 78.00 | 161.45 | 5.20 | 123.45 | 9.90 | 123.45 |
| β carotene (µg) | 15.00 | 50.45 | 24.00 | 505.45 | 323.00 | 492.72 | 565.00 | 769.09 | 35.00 | 510.90 | 78.00 | 530.90 |
| Thiamine (mg) | 0 | 0.10 | 0.50 | 0.12 | 0.30 | 0.19 | 0.90 | 0.18 | 0.50 | 0.18 | 0.60 | 0.20 |
| Riboflavin (mg) | 0.10 | 0.02 | 0.70 | 0.24 | 0.60 | 0.30 | 1.50 | 0.18 | 0.80 | 0.22 | 0.80 | 0.31 |
| Niacin (mg) | 0.38 | 0.01 | 1.40 | 0.41 | 1.55 | 0.49 | 2.20 | 0.8 | 1.67 | 0.54 | 2.70 | 0.56 |

VC: Vermicelli; UM: Upma

control (Table 4). All the five-tuber vermicelli *upma* provide good amount of nutrients. However, these variations were not considerable and can be attributed to *in situ* characters of the tuber itself[9-11].

**_In vitro_ starch digestibility of Lesser Yam (LY) vermicelli *upma***

The *in vitro* starch digestibility of LY-based vermicelli *upma* (Fig. 1) increased with increase in time of digestion. Lower digestibility was recorded at 30 min (14.46±0.11) and was maximum at 120 min (20.62±0.09). The present study on *in vitro* starch digestion showed slow starch digestibility of LY vermicelli *upma* may be due to big granular size of the tuber flour. Slow digestion indicates high potential to be used as functional ingredient in preparing foods because people require glycemic control during metabolic disorder (Fig. 1).

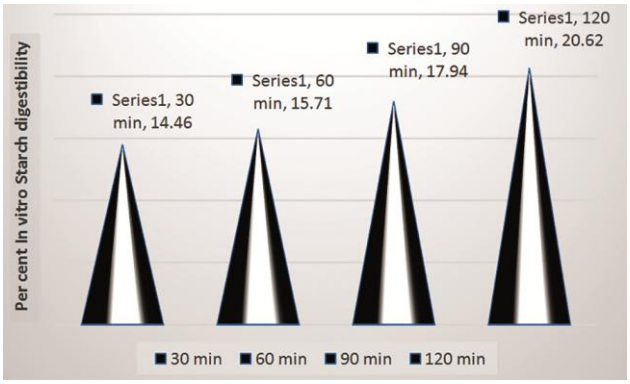


Fig. 1 — *In vitro* starch digestibility of minor tuber based fasting vermicelli *upma*

**Glycemic index of Lesser Yam (LY) based vermicelli *upma***

The glycemic index measures the incremental area under the blood glucose response curve of a test food containing 50 g of carbohydrates, represented as a percentage of the response to the same amount of carbohydrates from a reference food consumed by the same subject. Foods are classified as low, medium and high based on GI (American Diabetes Association). Foods with low GI are preferred during fasting and non-communicable diseases like diabetes, cardiovascular diseases etc., as they are slowly digested and absorbed causing slower and smaller rise in blood sugar level and also help to sustain hunger for long period by having high satiety value, such

Table 5 — Glycemic index of vermicelli *upma* among non-diabetics

| Foods | Mean±SD | Range | t-value |
|---|---|---|---|
| Lesser yam vermicelli *upma* | 52.34±0.64 | 51.56–53.93 | |
| Wheat vermicelli *upma* | 69.26±1.47 | 66.12–70.87 | 33.19** |

**- Highly significant

foods provide extra health benefits to people. As starch is main constituent of tubers, it plays a considerable role in managing non-communicable diseases besides providing satiety[12]. In contemporary era, due to lifestyle changes, there is an increased risk of metabolic disorders. Owing to this, rate of starch digestibility becomes a point of concern, often slow digestible foods aids in low glycemic index which is directly related to curing metabolic disorders.

Glycemic index of particular food helps in predicting time required to release glucose in blood which is beneficial during different metabolic disorders. *In vitro* starch digestibility was studied and the results are presented in Table 1-5. Predicted glycemic index was tabulated using values obtained.

#### Predicted glycemic index of LY based vermicelli *upma*

The glycemic index was predicted to be 53.61 which was grouped as low according to American Diabetes Association (2019).

#### *In vivo* glycemic index of LY vermicelli *upma* among non-diabetics

The comparison between the glycemic index of LY vermicelli *upma* and wheat vermicelli (control) *upma* is depicted in Table 5. The LY vermicelli *upma* had significantly lower glycemic index of 52.34 when compared with wheat vermicelli *upma* (69.26). Low IVSD of LY vermicelli upma lead to lower PGI and *in vivo* GI. This may be due to low amylopectin content of tubers which facilitates slower absorption from GIT and into the cells which further results in lower total area under curve (AUC), this explanation is in line with the results[13]. Low GI of LY vermicelli upma may also be due to modification of starch to resistant starch during processing. Preparation of vermicelli upma undergoes three steps viz., extruding, roasting and sautéing. As reported by the study[14], repeated cycles of processing lead to conversation of starch to resistant starch, which helps in slow digestion and thus low GI (Table 5).

#### Glycemic response of non-diabetic volunteers

The blood glucose response of capillary blood, to the consumption of LY vermicelli *upma* in comparison to wheat vermicelli *upma* among non-diabetic subjects is indicated in Fig. 2.

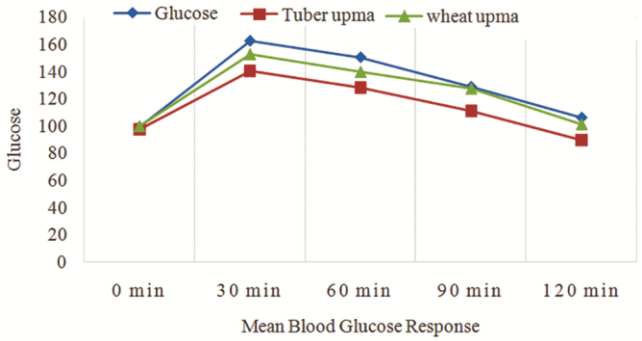


Fig. 2 — Glucose response of test and control foods to glucose in non-diabetic volunteers

Peak was reached at 30 min and values for test meal were lower (140.28 mg/dL) when compared to reference meal (162.44 mg/dL) and control meal (152.84 mg/dL) in non-diabetic volunteers. Similar trend was observed after 60, 90 and 120 min of consumption. Further, after 120 min the blood glucose response was lower than basal (fasting) level.

## Conclusion

Tubers are reported to be a good source of starch and have high protein digestibility, medium glycemic index, phyto-chemicals and other nutrients. However, food products developed by the minor tubers are novel products which provide micro and macro nutrients besides being rich in resistant starch which help in slow release of glucose that helps in managing the blood glucose level of diabetic patients. glycemic control. Hence, minor tuber flour can be completely replaced in development of foods and converting these tubers into other value-added products may add to the best utilisation of tubers as functional and health foods.

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## Conflict of Interest

Authors declare there are no conflicts of interest

## Author's Contributions

PM participated in designing of the research, conducted the research, interpreted research data and drafted the manuscript. BP supervised and advised the research work, helped to draft and edit the manuscript, provided mentorship support and responsible for managing the funds. KU coordinated the experiment and helped in revising the manuscript. All authors have read and approved the final version of the article.

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