SHORT COMMUNICATION

Nutritional enhancement of extruded vermicelli through incorporation of finger millet and carrot pomace

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ABSTRACT

This study focused on the development and characterization of nutrient-enriched cold-extruded vermicelli using composite flour blends incorporating finger millet, pulse flour, corn flour, semolina, and carrot pomace. Two formulations were developed: control (100% semolina), composite formulation V1 (40% finger millet, 20% corn flour, 20% red gram pulse flour, 10% semolina,10% carrot pomace). Cold extrusion was performed using a single-screw extruder. Vermicelli demonstrated superior nutritional, functional attributes. Proximate analysis revealed that vermicelli had significantly higher protein (17.05 g), dietary fiber (14.7 g), and iron (6.58 mg) compared to the control. The fatty acid profile showed increased monounsaturated (0.49 g) and polyunsaturated fatty acids (1.33 g), as compared to the control (0.2 g monounsaturated and 0.6 g polyunsaturated fatty acids), indicating a healthier lipid composition. The cooking quality of the vermicelli was improved, as evidenced by a higher water absorption capacity (3.47%), expansion ratio (2.62), and a low cooking loss (2.21%), which falls within the acceptable range. These results demonstrate the potential of incorporating finger millets and carrot pomace as functional ingredients in the development of health-oriented, ready-to-cook vermicelli, offering enhanced nutritional quality along with value-added functional benefits.

Keywords: Finger millet, carrot pomace, vermicelli, cold extrusion, composite flour

The increasing consumer demand for convenient, ready-to-cook foods with added health benefits has led to the reformulation of traditional products like vermicelli. Vermicelli is a type of traditional extruded product typically made from refined wheat flour and consumed widely in many Asian and Middle Eastern countries. It is thin, dried, and often roasted before use in both sweet and savory preparations. While conventional vermicelli is low in fiber and micronutrients, its nutritional value can be enhanced by incorporating composite flours from millets, pulses, or vegetables (Kulkarni *et al*., 2012).,Conventional vermicelli made from refined semolina lacks key elements like dietary fiber, essential amino acids, and micronutrients. Incorporation of functional ingredients offers a viable approach to enhance the nutritional profile of vermicelli (Kulkarni *et al*., 2012). Ragi, also known as finger millet (*Eleusine coracana*), is a nutrient-dense, gluten-free cereal that is well known for its health advantages. Because of its high calcium content, it is beneficial for bone health, especially in women, children, and the elderly. Finger millet is high in calcium and also has a considerable quantity of protein and dietary fiber, which help with digestion, blood sugar balance, and muscular growth. Along with B-vitamins like thiamine, riboflavin, and niacin, it also offers vital minerals like iron, magnesium, phosphorus, potassium, and zinc (Devi *et al*., 2014). A by-product of the juice-making process, carrot pomace is rich in beta-carotene and dietary fiber, providing sustainability and nutritional advantages (Verma *et al.*, 2020). Functional ingredients like millets and vegetable pomace maintain their nutritional value when cold-extruded vermicelli is made without the use of heat (Gandhi *et al.*, 2022), this technique preserves bioactive substances like fiber and antioxidants while improving texture, nutrient density, and acceptability. The addition of finger millet and carrot pomace enhances vermicelli's health advantages and qualifies it for use in food formulations with added value (Shobana *et al*., 2013). Value addition is a successful tactic to boost the popularity of underutilized fruit and vegetable species, decrease post-harvest waste, and guarantee their year-round availability (Dissanayake *et al.*, 2023). Thus, the goal of the current study was to improve the nutritional value of extruded vermicelli by adding carrot pomace, red gram pulse flour, and finger millet corn flour.

Finger millet, corn flour, red gram pulse and semolina were procured from Agra markets. Red gram was prepared by cleaning and lightly roasting the dal to enhance flavor and digestibility. After cooling, it was finely ground using a mixer grinder and sieved to obtain uniform flour, then stored in an airtight container. A Kuvings B1700 juicer was used to extract the carrot pomace, which was then collected, dried in a hot air oven at 60°C for four hours, powdered into a fine powder, and kept in an airtight container until it was needed again.

- Two formulations were developed: Control (100% semolina)
- Composite formulation Vermicelli (V1) (40% finger millet, 20% corn flour, 20% red gram flour, 10% semolina,10% carrot pomace) presented in Table 1.

The composite flour blends were prepared as per the formulation and mixed thoroughly for uniform distribution. A single-screw extruder (G.L. Extrusion Systems, 5 HP) equipped with a 2 mm circular die was then used to cold extrude these blends.The extrusion was carried out at ambient temperature without external heating, which helps retain heat-sensitive nutrients such as vitamins, antioxidants, and bioactive compounds (Gandhi *et al.*, 2022).The extruded strands were cut to uniform lengths and air-dried under shade at room temperature for 6–8 hours to reduce moisture content and ensure better shelf stability. After drying, In order to preserve it for later use and analysis, the vermicelli was sealed in low-density polyethylene (LDPE) bags and kept at room temperature (Kumar and Sharma *et al*., 2020).

Protein, fat, carbohydrate, dietary fiber, amylose and amylopectin were analyzed using AOAC, (2000) methods. Mineral analysis was carried out using Atomic Absorption Spectroscopy (AAS) following the standard procedures outlined by AOAC (2000). Fatty acid profiles were determined by gas chromatography and HPLC, respectively. Cooking quality *i.e.,* Water absorption, cooking loss, and expansion ratio were determined using standard methods described by AACC (2000). Sensory Evaluation was conducted by 9 point hedonic scale. Statistical analysis was conducted using SPSS with significance at $p \leq 0.05$.

The data presented in Table 2, highlights the nutritional improvements observed in the formulated vermicelli compared to the control. Protein content in the vermicelli was considerably higher (17.05 g) than the control (8.86 g), attributed to the inclusion of pulse flour and finger millet. This finding is supported by Rani *et al.* (2021), who reported increased protein levels in vermicelli enriched with legume flours due to their high lysine content. Dietary fibre content also increased significantly in the vermicelli (14.7 g) compared to the control (3.30 g), which aligns with Verma *et al.* (2020), who found that carrot pomace significantly enhances fibre content when added to cereal-based products.

Amylose content was higher in the vermicelli (13.3%) than in the control (10.3%), which may support improved glycaemic response; this is consistent with the results of Pradeep and Guha (2011), who observed elevated amylose levels in fibre-rich extruded products. Fat content was slightly reduced in the formulated vermicelli (1.0 g) relative to the control (1.4 g), in agreement with Sharma *et al.* (2015), who reported decreased fat retention in millet-based noodles. Carbohydrate levels remained similar in both samples (71.8 g in vermicelli and 72.3 g in control), indicating that functional ingredient addition had minimal impact on total carbohydrate content.

The data presented in Table 3**,** highlight the mineral content of vermicelli showed a substantial improvement over the control. Calcium content increased from 12.6 mg in the control to 24.2 mg in the formulated vermicelli, while iron content increase from 1.22 mg in the control 6.58 mg in formulated vermicelli. This increase is primarily due to the inclusion of finger millet, which is naturally rich in calcium and iron (Kumar and Sharma, 2020). Similar enhancements in mineral content through the use of millets have been reported by Shobana *et al.* (2013). The contribution of carrot pomace may have further improved the iron and calcium levels, consistent with findings by Verma *et al.* (2020) also reported increase in mineral content in extruded products enriched with fruit and vegetable residues.

The Fatty Acid Analytical technique used in the study is used to compare the fatty acid data shown in Table 4 between the profiles of the control and formulated vermicelli. The data reveal that the formulated Vermicelli contains significantly higher levels of beneficial unsaturated fatty acids. Specifically Mono unsaturated fatty acid increased from 0.2 g in the control to 0.49 g in vermicelli while polyunsaturated fatty acid showed an even more remarkable increase from 0.6 g in the control to 1.33 g in vermicelli. Although there was an increase in saturated fatty acid in formulated Vermicelli (0.47 g) compared to the control (0.2 g), the overall profile shows a favorable shift toward unsaturated fats. Unsaturated fatty acids, especially monounsaturated and polyunsaturated fats, are good for cardiovascular health because they lower low-density lipoprotein (LDL) cholesterol, promote anti-inflammatory reactions, and enhance lipid profiles in general. They are linked to a lower risk of metabolic diseases and heart disease when included in the diet Schwab *et al.* (2014),.These results are consistent with earlier studies, by Verma *et al.*, (2020) and Pradeep and Guha (2011), which emphasized the enhancement of fatty acid profiles through the incorporation of fiber-rich and millet-based ingredients. Therefore, the vermicelli demonstrates an improved lipid profile, supporting its development as a healthier, functional food product.

Data from the cooking quality table is shown in Table 5. Three important factors are compared between the control and vermicelli in the Cooking Quality: water absorption, cooking loss, and expansion ratio.The

Cooking Quality compares three key parameters water absorption, cooking loss, and expansion ratio between the control and vermicelli. The results indicated that vermicelli demonstrated enhanced cooking quality. Water absorption increased from 3.26% in the control to 3.47% in formulated vermicelli, suggesting improved hydration and rehydration ability during cooking, likely due to the presence of fibre-rich ingredients like carrot pomace and finger millet. Cooking loss, although slightly higher in vermicelli (2.21%) than in the control (1.83%), remained within acceptable limits, indicating that the product retained its structural integrity despite its elevated fibre content. The expansion ratio was also higher in vermicelli (2.62) compared to the control (2.18), reflecting better swelling capacity and increased volume post-cooking. These improvements align with findings by Devi *et al.* (2020) and Sharma *et al.* (2015), who reported that millet-based and vegetable pomace-enriched noodles exhibited superior cooking characteristics. The results confirm that incorporating functional ingredients into vermicelli formulations enhances cooking quality, making the final product more desirable in terms of texture, cooking stability, and consumer appeal. The improved cooking quality of vermicelli is attributed to the functional ingredients used. The higher water absorption is due to the presence of dietary fiber from carrot pomace and finger millet, which enhances hydration during cooking (Verma *et al.*, 2020). Slightly increased cooking loss may result from fiber disrupting the starch matrix, but it remains within acceptable limits, indicating structural stability (Devi *et al.*, 2020). The higher expansion ratio reflects better swelling, supported by the starch and amylose content in finger millet and pulses, contributing to a desirable texture and improved mouthfeel (Pradeep and Guha, 2011; Sharma *et al.*, 2015).

The sensory evaluation data shown in Table 6, the prepared Vermicelli sample was more palatable than the control sample in every sensory category. The sensory evaluation results indicated that formulated Vermicelli demonstrated better acceptability the control sample across all sensory attributes. Formulated Vermicelli received higher mean scores for appearance (7.45), colour (7.81), flavour (7.30), texture (7.60), aftertaste (6.95), and overall acceptability (7.85), compared to the control with respective scores of 6.45, 6.45, 6.90, 6.91, 6.35, and 6.75. These improvements can be attributed to the incorporation of functional ingredients such as finger millet and carrot pomace. Similar enhancements in sensory quality were reported by Devi *et al.* (2020), who found that vegetable pomace improved the color, flavor, and overall acceptability of noodles. Pradeep and Guha, (2011) also demonstrated improved sensory attributes in finger millet-based vermicelli. Furthermore, Banu *et al.* (2022) noted enhanced texture and appearance in extruded products developed with composite flours.

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CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Table 1: Composite flour

Sample	Finger Millet	Corn Flour	Pulse Flour	Semolina	Carrot Pomace
Control	–	–	–	100 g	–
V1	40 g	20 g	20 g	10 g	10 g

Table 2: Nutritional analysis of vermicelli

Parameters	Control	Vermicelli	T-value
Protein (g)	8.86±0.12	17.05±0.3	*4.3
Fat (g)	1.4±0.05	1.0±0.1	*0.04
Carbohydrate (g)	72.3±0.6	71.8±0.5	*0.01
Dietary Fiber (g)	3.30±0.07	14.7±0.7	*4.3
Amylose (%)	10.3 ±0.1	13.3±0.8	*0.03

Mean SD is used to express values, while p < 0.05 indicates significance.

Table 3: Mineral Analysis of vermicelli

Mineral	Control	Vermicelli
Calcium(mg)	12.6±0.7	24.2±0.9
Iron (mg)	1.22±0.5	6.58±0.7

Values are expressed in mean SD and significant at $p \leq 0.05$

Table 4: Fatty acid analysis of vermicelli

Sample	SFA (g)	MUFA (g)	PUFA (g)
Control	0.20	0.20	0.60
Vermicelli	0.47	0.49	1.33

Mean SD is used to express values, while p < 0.05 indicates significance.

Table 5: Cooking quality of vermicelli

Parameters	Control	Vermicelli	T Value
Water Absorption (%)	3.26±0.8	3.47±0.9	*6.35
Cooking Loss (%)	1.83±0.7	2.21±0.7	*0.009
Expansion Ratio	2.18±0.7	2.62±0.3	*0.002

Mean SD is used to express values, while p < 0.05 indicates significance.

Table 6: Sensory evaluation of vermicelli

Attributes	Control	Vermicelli 1
Appearance	6.45 ± 0.70^{b}	7.45 ± 0.73^{a}
Colour	6.45 ± 0.12^{b}	7.81 ± 0.24^{a}
Flavour	6.90 ± 0.41^{ab}	7.30 ± 0.14^{a}
Texture	6.91 ± 0.20^{b}	7.60 ± 0.07^{a}
Aftertaste	6.35 ± 0.14^{b}	6.95 ± 0.12^{a}
Overall Acceptability	6.75 ± 0.14^{b}	7.85 ± 0.45^{a}
F-value	**9.38***	**21.94****

Mean SD is used to express values, while p < 0.05 indicates significance.