

Invitro Starch Digestibility and Glycemic Index of Optimized Acha, Finger Millet and Cocoyam Composite Flour

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Abstract

The study was undertaken to develop composite flour from *Acha*, finger millet and cocoyam flour using the I- optimal mixture design at different combination levels of Acha (78-80 %), finger millet (15-20 %) and cocoyam (5-10 %) flour respectively. Eleven (11) runs were generated and the in-vitro starch digestibility and glycaemic index were evaluated using standard methods. The rapidly digestible starch (RDS), slowly digested starch (SDS) and resistance starch (RS) results ranged between 4.54- 23.74 %, 10.65- 19.93 %, and 9.57 – 15.68 respectively. The sample with 73.75 (*acha* flour): 17.50 (finger millet flour): 8:75 (cocoyam flour) had the highest resistance starch. Also, the Glycaemic index (GI) ranged between 58.93 and 63.48 % which is classified as medium glycaemic index. In view of the glycaemic index range observed in these flour mixtures they can be used to substitute high glycaemic index carbohydrate-based food. However, the flour mixture containing (71.67 % Acha flour, 18:33 % finger millet flour and 10.00 % cocoyam flour) could be an ideal option in dietary lifestyle modification.

Introduction

Millets belong to the Poaceae family and are small underutilized edible seeds packed with nutritional benefits. They are an important group of cereal grains known for their resilience and can thrive in harsh climatic conditions (Muskan et al., 2025). *Acha* (*Digitaria exilis*) also known as hungry rice or *fonio* millet is a staple diet for around 4 million people in various parts of Africa, especially the northern part of Nigeria (Agrawal, 2023). *Acha* and finger millets possess nutraceutical properties that may aid in the prevention and management of type 2 diabetes and prediabetes (Nanje-Gowda et al., 2025). Cocoyam is widely cultivated in Nigeria with a recorded annual production of above 3.450 million metric tonnes (Falade and Okafor, 2015). It is also recognized for its nutritional properties and its application in food as a thickener. It has been used in managing chronic diseases, supports cardiovascular health by regulating blood pressure and reducing the risk of hypertension and stroke (Falade and Okafor, 2015). Carbohydrate rich foods generally trigger a swift response rise in blood glucose levels resulting in early postprandial hyperglycemia and hyperinsulinemia referred to as high glycaemic index foods which poses a risk to developing diabetes, obesity and some other non-communicable diseases (NCDs). These diseases are identified as threat to progress towards the 2030 Sustainable Development Agenda targeted at reducing by one-third the probability of death from any of the four main NCDs between ages 30 and 70 years in 2030(Oso, 2023).

The process of optimization involves determining the best combination of ingredients or food product that are marketable, of high quality to use and waste elimination. This study examines the starch digestibility and glycaemic indices (GIs) of these composite flours for possible use as functional foods in the dietary management of NCDs such as diabetes which has been a primary contributor to hospitalizations and mortality in tertiary healthcare settings in Nigeria (Oso, 2023).

Materials and Methods

Freshly harvested cocoyam (*Colocasia esculenta*) of 2 kg was purchased from the National Root Crop Research Institute Umudike, Nigeria, while 5 kg of Acha (*Digitaria exilis*) and 3 kg of finger millet (*Eleusine coracana*) grains were obtained from Makurdi Morden market, Makurdi Benue State Nigeria respectively. The research was carried out in the Food Processing Laboratory, Department of Food Science, Ebonyi State University, Abakaliki, Ebonyi State, Nigeria.

Preparation of acha, millet and cocoyam composite flour

Acha (fonio) and finger millet grains were sorted and wet cleaned followed by drying and milling (attrition mill: R175A Model) into flour as described by Ayo et al. (2018) while the cocoyam corms were sorted, washed, peeled and cleaned under running water, drained and cut into thin slices of about 1 cm. This was then dried at 60 °C oven for 9 h, milled (attrition mill: R175A Model) into flour, sieved using 100 µm sieved and packaged in Ziploc bags (Falade and Okafor, 2015).

Formulation of the composite flour blends

The blends were formulated using the I- optimal mixture design of the Design Expert software (version 12.0.3, Stat-Ease Inc., USA) to generate eleven (11) runs (Table 1) from different combination levels of *acha* (78-80 %), finger millet (15-20 %) and cocoyam flour (5-10 %).

Table 1. Mixture I-Optimal Design using three variables for composite flour formulation

Runs	AC (X ₁ %)	FM (X ₂ %)	CY (X ₃ %)
1	78.33	15.00	6.67
2	75.00	15.00	10.00
3	78.33	16.69	5.00
4	80.00	15.00	5.00
5	72.50	20.00	7.50
6	73.75	17.50	8.75
7	75.00	18.33	6.67
8	70.00	20.00	10.00
9	71.67	18.33	10.00
10	76.25	16.25	7.50
11	76.67	18.33	10.00

AC= Acha flour, FM= Finger millet flour and CY= Cocoyam flour

Determination of in-vitro -starch digestibility and glycaemic index

The invitro starch digestibility was determined using the method described by Englyst (1992). The digestion kinetics non-linear model was used to assess slowly digestible starch (SDS), rapidly digestible starch (RDS) and resistance starch (RS). The amount of glucose released after 120 min of digestion is known as resistant starch, whereas the amount released between 20 and 120 min is known as slowly digested starch (SDS), and the amount released after 20 min is known as rapidly digestible starch (RDS). For the glycaemic index, the incremental area under the blood glucose response curve of a 50 g carbohydrate portion of the test food (IAUC) expressed as a percent of the same amount of the carbohydrate from a standard food (IAUCS) taken by the same subject. The area under the curve was calculated as the incremental area under the blood glucose response curve. Where 50 g is the Glucose reference test). The GI for each food was calculated using Equation 1:

$$GI = (IAUC/IAUCS) \times 100 \tag{1}$$

Where GI= Glycemic index, IAUC= Incremental area under curve of test food, IAUCS= Incremental area under curve of standard (white bread)

Statistical Analysis

Statistical analysis was conducted using Statistical Package for Social Science (SPSS, version 20 for Windows and means were separated using Duncan's Multiple Range Test. Results were reported as Mean±SD of triplicate measurements

Results and Discussion

The results of the in-vitro starch digestibility fractions and glycaemic index revealed notable disparities among the flour samples at significant ($p < 0.05$) difference as presented in Table 2. The rapidly digestible starch (RDS) ranged between 4.54- 23.74 %. The RDS value at run 4 (80 % Acha flour, 15 % finger millet flour and 5 % cocoyam flour) is notably high and this implies a tendency of provoking high glucose in the blood stream when consumed. Hence lower values at run 5 (72.50 % Acha flour, 20.00 % finger millet flour and 7.50 % cocoyam flour) and 9 (71.67 % Acha flour, 18.33 % finger millet flour and 10.00 % cocoyam flour) would be more advantageous. The SDS ranged from 10.65- 19.93 %, and Run 6 (73.75 % Acha flour, 17.50 % finger millet flour and 8.05 % cocoyam flour) had the highest, implying a slower rate of digestion and glucose release. High resistant starch value ranging from 9.57 – 15.68 % were recorded in these samples. Resistant starch (RS) is a fraction of the starch that is not digested in the small intestine and enters the colon unchanged, and intestinal micro-organisms ferments. Run 6 (73.75 % Acha flour, 17.50 % finger millet flour and 8.05 % cocoyam flour) and 7 (75 % Acha flour, 18.33 % finger millet flour and 6.67 % cocoyam flour) would offer having high RS will be more beneficial as prebiotics and it could offer a feeling of satiety which could be advantageous in weight management. Several factors can explain the difference found in the resistant starch quantities, as follows: interaction of starch with different components present in the food system such as proteins, fats and the botanical source of starch in the individual samples. While the GI and TC ranged between 58.93- 63.48 % and 64.14- 73.28 % respectively. The GI results indicate that the samples in this work are classified as having a medium/average (GI within 56 to 69) according to international table of GI as reported by Foster-Powell et al. (2002), The glycaemic index is lower than instant *fufu* powder blends made from cassava starch extrudates and orange sweet potato (OFSP) which ranged from 47.26 to 96.40 % as reported by Kolawole et al. (2023). It was observed that the sample run 4 (80 % Acha flour, 15 % finger millet flour and 5 % cocoyam flour) had the highest GI of 63.48 which could probably be as result of its high RDS.

Table 2. Starch Digestibility and Glycaemic Index of Optimized Acha, Finger Millet and Cocoyam Flour Blends

Runs	RDS	SDS (%)	RS	GI
1	19.85 ^b ±0.01	10.65 ⁱ ±0.01	10.58 ^g ±0.14	62.63 ^b ±0.05
2	8.92 ^e ±0.02	18.81 ^f ±0.01	13.73 ^e ±0.00	60.51 ^d ±0.01
3	7.57 ^f ±0.01	19.09 ^e ±0.06	13.41 ^e ±0.62	60.30 ^d ±0.05
4	23.74 ^a ±0.05	16.23 ^j ±0.01	9.57 ^h ±0.55	63.48 ^a ±0.00
5	4.54 ^k ±0.00	19.73 ^b ±0.00	15.39 ^{ab} ±0.01	59.92 ^e ±0.41
6	5.36 ⁱ ±0.00	19.93 ^a ±0.02	15.68 ^a ±0.11	59.02 ^f ±0.03
7	16.82 ^c ±0.00	17.56 ^h ±0.02	11.57 ^f ±0.00	62.05 ^c ±0.00
8	6.19 ^h ±0.02	19.31 ^d ±0.01	14.21 ^d ±0.35	59.92 ^e ±0.03
9	4.83 ^j ±0.00	19.52 ^c ±0.02	14.97 ^{bc} ±0.02	58.93 ^f ±0.65
10	6.24 ^g ±0.18	19.29 ^d ±0.02	14.57 ^{cd} ±0.00	60.00 ^e ±0.03
11	8.95 ^d ±0.00	18.77 ^j ±0.00	13.70 ^e ±0.02	60.59 ^d ±0.05

AC= Acha flour, FM= Finger millet flour and CY= Cocoyam flour
RDS= Rapidly digested starch, SDS= Slowly digested starch, RS= Resistance starch, GI= Glycaemic index and
TC= Total carbohydrate

Conclusion



The study revealed that the optimization of acha, finger millet and cocoyam composite flour varied in some nutritionally important starch digestibility parameters analysed. All the samples exhibited medium glycaemic index value. However, run sample 6 (75.75 % acha, 17.50 % finger millet and 8.75 % cocoyam flour) had the highest slowly digestible starch while the lowest glycaemic index was sample run 9 (71.67 % acha, 18.33 % finger millet and 10.00 % cocoyam flour). This flour combination can be used as a functional food owing to its average glycaemic index and further study is recommended on the glycaemic load and sensory properties of the meal.

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