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Macronutrient Composition and Starch Type of Food Formulations Based on Rice and Cowpea Varieties

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Abstract One of the principles of good nutrition for diabetics is a balanced diet rich in dietary fiber. However, the carbohydrate food most consumed by diabetics in Côte d'Ivoire is rice, known to be high in carbohydrates and low in dietary fiber. The aim of this study was to develop rice- and cowpea-based dietary formulations, rich in dietary fiber, for the dietary management of diabetic patients or people at risk of diabetes in Côte d'Ivoire. To this end, two cowpea varieties were blended with three rice varieties in different proportions (0, 25 and 50%). Macronutrient compositions and starch, amylose and amylopectin contents were analyzed. Protein, fiber and amylose contents were higher in the different cowpea varieties than in the rice varieties. Protein, fiber and amylose values were 24.34 ± 0.04 to 25.37 ± 0.05%; 4.78 ± 0.01 to 6.33 ± 0.02% and 22.59 to 23.1% respectively in red and white cowpeas. In contrast, the three rice varieties recorded respective values of 7.32 ± 0.12 to 8.84 ± 0.01% protein; 1.55 ± 0.06 to 1.86 ± 0.01% fiber and 14.56 to 15.3% amylose. The addition of cowpea to rice significantly ($P < 0.05$) improved the nutritional value of the formulations, with an increase in protein, fiber and amylose content compared to rice varieties. This increase in content was a function of the rice-cowpea pairing (25% cowpea -75% rice and 50% cowpea -50% rice). The protein, fiber and amylose contents of the formulations were respectively 10.45 ± 0.02 to 18.54 ± 0.02%; 3.06 ± 0.005 to 5.8 ± 0.61%; 24.61 to 30.08%. Daily consumption of a cereal/legume combination would be beneficial in correcting and/or preventing metabolic diseases, in particular type 2 diabetes.

Keywords: *food formulation, rice, cowpea, amylopectin, amylose nutritional value*

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1. Introduction

Diet has a considerable impact on the prevalence of chronic diseases such as diabetes and hypertension, and is thus a crucial aspect of overall diabetes management in the Kimokoti and Millen study [1]. The diet prescribed for diabetics must take into account not only caloric intake but also the ability of foods to induce a high or low glycemic response, according to Madhu [2]. According to Sukar et al [3]. Cereal-based diets have proved effective in controlling hyperglycemia. In West Africa, the promotion of local cereals and legumes is a major challenge, given the rapid increase in the population and their high demand in both rural and urban areas, according to Bricas [4]. For example, according to Beninga et al. [5], cereals and legumes are not only the traditional staple diet, but also important staple foods for the populations of northern Côte d'Ivoire (Sénoufo, Malinké and Mahouka) and foreign populations emigrating from South-Sahelian African countries. According to Ramdath et al. [6], several scientific studies have shown that when cereals are eaten with pulses in the same meal, the glycemic index of the meal is lower than when cereals are eaten on their own. In Côte d'Ivoire, cereals account for 30 percent of the population's food consumption, and are one of the main sources of energy and nutrients for these populations, according to MINADER [7]. Cereals contain mainly carbohydrates in the form of starch, but also a sufficient quantity of bioactive substances that could be effective in controlling hyperglycemia in the work of Boudries-Kaci and Robet et al. [8,9]. As for legumes, the interest in them is linked to their low price and their high protein and dietary fiber content. They are low in fat and are the second most important source of food after cereals. Pulses also contain a number of micronutrients and phytochemicals which, according to the FAO [10], offer a range of health benefits. According to a recent FAO study [11], certain pulses such as cowpeas and Hechi beans have antioxidant capacities. Among cereals, rice is the most widely consumed in the world, with consumption estimated at 105 kg/person/year according to Islam et al [12]. This staple is consumed every day, often more than three times a day, with different cooking methods depending on the amount of water used. Cowpea (Vigna unguiculata. F.) is one of the most widely consumed legumes in West Africa. In a study by Kouakou [13], it

was the main source of protein for rural populations. Cowpea contains an average of 23-25 percent protein and 50-67 percent starch, giving it an important role in combating protein deficiency among consumers). Some research has shown that complementary food formulas for young children containing 25 percent cowpea and 75 percent rice could have around 13 percent good-quality protein, thanks to the contribution of the lysine contained in cowpea and the methionine provided by rice in the study by Sidibé et al. [14].

Surveys of cereal-legume consumption levels and the extent of metabolic diseases have shown that some Ivorian communities consume these recipes with combinations of 75 percent rice and 25 percent cowpea, with a consumption frequency of 3 to 4 times a week. The aim of this study was to develop food formulations to improve the nutritional characteristics of recipes based on three varieties of rice and two varieties of cowpea, with a view to helping people with or at risk of diabetes.

2. Materials and Methods

2.1. Biologicals Material

Three rice varieties (black, white and brown) and two cowpea varieties (red and white) constituted the biological material. These foods were purchased respectively at the market and in a supermarket in Abobo commune (Abidjan, Côte d'Ivoire).

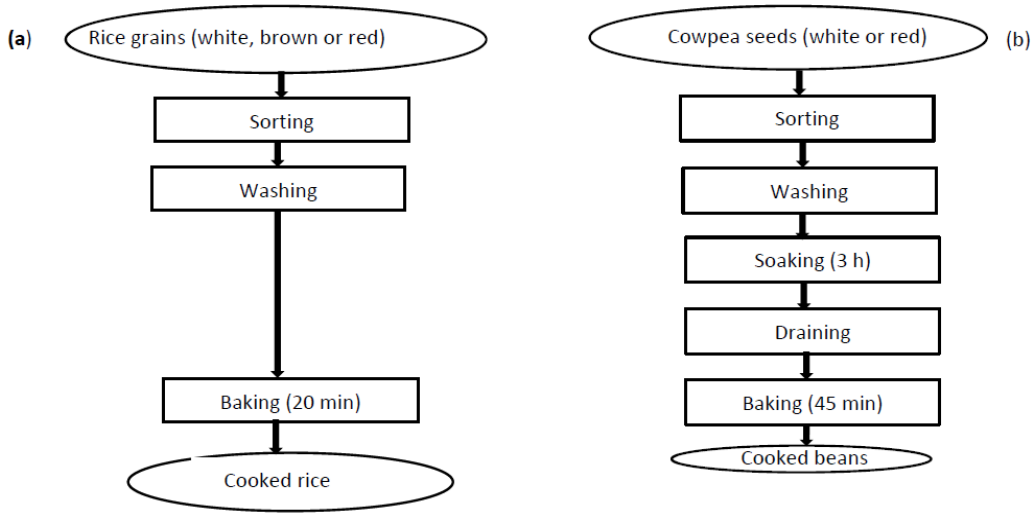

Figure 1. Rice preparation (a); Cowpea preparation (b)

2.2. Methods

2.2.1. Preparation of Rice and Cowpea Samples

Black, white and red rice samples were sorted separately, washed and then cooked in water for around 20 min, at a rate of 250 g rice in 500 mL water. Similarly, white and red cowpea samples were separately sorted, washed and then soaked in tap water for three (3) hours before being boiled in water for approximately 45 min, at a rate of 250 grams of cowpea in 450 mL of water. These foods were cooked at the Laboratoire de Biochimie Alimentaire et Technologie des Produits Tropicaux (LBATPT) (Figure 1).

2.2.2. Food Formulations

The different grains of cooked rice and cowpea were oven-dried at 45°C for 48 h, then ground using a blender (Moulinex, France). Binary formulations based on rice and cowpea were produced using the method of Assita et al [15]. The three rice varieties and the two cowpea varieties were used to produce seven food formulations in the proportions shown in Table 1. Samples of rice varieties, cowpeas and food formulations were stored in airtight boxes for biochemical analysis.

Table 1. Developing food formulations

Foods studied	Composition
WR	100 percent white rice
BR	100 percent black rice
BRr	100 percent brown rice
RC	100 percent red cowpea
WC	100 percent white cowpea
50WR–50RC	50 percent white rice + 50 percent red cowpea
50WR–50WC	50 percent white rice + 50 percent white cowpea
75WR–25RC	75 percent white rice + 25 percent red cowpea
75WR–25WC	75 percent white rice + 25 percent white cowpea
50BR–50RC	50 percent black rice + 50 percent red cowpea
50BR–50WC	50 percent black rice + 50 percent white cowpea
75BR–25RC	75 percent black rice + 25 percent red cowpea
75BR–25WC	75 percent black rice + 25 percent white cowpea
50RBRr–50RC	50 percent brown rice + 50 percent red cowpea
50BRr–50WC	50 percent brown rice + 50 percent white cowpea
75RBr–25RC	75 percent brown rice + 25 percent red cowpea
75RBr–25WC	75 percent brown rice + 25 percent white cowpea

Note: BR: black rice; WR: white rice; BRr: brown rice; WC: white cowpea; RC: red cowpea

2.2.3. Biochemicals Analysis of Samples

Lipid, protein, crude fiber, ash and moisture contents were determined according to AOAC standard methods [16] in triplicate tests.

Lipid content was determined by the Soxhlet extraction method. Protein content was determined by the Kjedahl method. Carbohydrate content (% of dry matter) was estimated by FAO differential calculation [18]. The energy value (EV) was determined using the Merril and Watt thermal coefficients [17] adopted by FAO.

Starch, amylose and amylopectin levels were determined using the Jarvis and Walkers method [18].

2.4. Statistical Analysis

Statistical analysis of the parameter data involved calculating the mean and standard deviation. Statistical differences between samples and measured parameters were verified with ANOVA using XLSTAT software version 2016.02.

3. Results

3.1. Macronutrient Content and Energy Value of Samples

3.1.1. Rice and Cowpea Varieties Samples

The overall aim of this study was to contribute to improving the nutritional values of rice- and cowpea-based culinary recipes for the management of type 2 diabetes. The nutritional characteristics of the three rice varieties (RB, RBr, RN) and the two cowpea varieties (NB, NR) are presented in Table 2. The highest ash values were recorded in the two cowpea varieties (2.2 and 2.85 percent) and the lowest in the three rice varieties (1.03 to 1.06 percent). According to Mansouri and Ammouche [20,21], these cowpeas are generally comparable to other legumes such as chickpeas, lentils and rice. The two samples of white and red cowpeas showed very high protein contents of 25.37% and 24.34% respectively. Whereas the three control rice samples (RB, RN and RBr) showed the lowest protein contents, with values of 7.32, 8.57 and 8.84% respectively. These results are in line with those reported by Gonçalves et al [22] who mentioned that cowpea is a good source of protein, with content values ranging from 20.3 to 39.4% DM. Speaking of lipid content, the results showed little variation for the different combinations, but differed from sample to sample. The low lipid content of legumes, more specifically cowpeas, could be explained by their botanical origin. Also, rice, which is a carbohydrate-based food, combined with cowpea did not significantly increase lipid content in the formulated samples. These results confirm those of Khalid et al [23], who recorded a lipid content of around 2.1 ± 0.1% in a wholemeal cowpea flour in Sudan.

Table 2. Biochemical composition of rice and cowpea varieties

	Humidity (Percent)	Ash (g/100g)	Protein (g/100g)	Lipids (g/100g)	Fibers (g/100g)	Carbohydrates (g/100g)	EV (Kcal/100g dry matter)
WR	9.6±0.2^{c}	1.06±0.2^{c}	7.32±0.12^{e}	0.85±0.06^{b}	1.55±0.06^{e}	81.17±0.14^{a}	355.44± 0.63^{a}
BR	11.27±0.5^{bc}	1.03±0.0^{c}	8.57±0.02^{d}	0.95±0.01^{b}	1.86±0.01^{c}	78.18±0.46^{b}	348.09±2.03^{ab}
BRr	11.9±1.1^{b}	1.05±0.0^{c}	8.84±0.01^{c}	0.95±0.01^{b}	1.69±0.01^{d}	77.23±1.07^{b}	346.33±4.55^{b}
RC	14.5±0.3^{a}	2.85±0.1^{a}	24.34±0.04^{b}	1.73±0.07^{a}	4.78±0.01^{b}	56.57±0.22^{c}	320±1.63^{c}
WC	10.9±0.91^{bc}	2.2 ±0.3^{b}	25.37±0.05^{a}	1.77±0.09^{a}	6.33±0.02^{a}	59.75±1.01^{d}	331.18±2.97^{ab}

Note: BR: black rice; WR: white rice; BRr: brown rice; WC: white cowpea; RC: red

Carbohydrates are macronutrients that provide the body with energy. Total carbohydrate contents in this work ranged from 56.57 to 81.17%. The highest total carbohydrate contents were recorded in the three rice varieties (77.23 to 81.17% DM carbohydrate), and the lowest contents in the two cowpea varieties, with respective values of 56.57% for red cowpea and 59.75% for white cowpea. These results are lower than those 115 reported by Goyon and Mestres [24] for rainfed rice, with contents ranging from 87.98 to 90.96% DM. Carbohydrates, particularly energetic substances, are clearly in the majority in cereals. Carbohydrates, particularly energetic substances, are clearly in the majority in cereals. These carbohydrate contents in cowpeas are in line with those found by Azaza et al [25], who showed that legumes contain 25-60% starch (carbohydrates). From an energy point of view, the three rice samples studied ranged from 346.33 ± 4.55 to 355.44 ± 0.63 Kcal/100g DM, with the highest energy values compared to the two cowpea samples with values of 320 ± 1.63 and 331.18 ± 2.97 Kcal/100g DM. In Aykroyd and Doughty [26], the energy values for cowpeas range from 280.98 to 364.2 kcal. This indicates the energy richness of varieties and species. The analytical data from this study reveal non-similarity with those found by these authors. These differences could be justified by the geographical area in which the raw materials (rice and cowpea) are grown, but also by the analytical methods used in the present study.3.1.2 Food Formulations Samples Based on Rice and Cowpea Varieties

The nutritional characteristics of the food formulations developed are presented in Table 3. The ash content in the samples based on 50% rice and 50% cowpea showed a significant increase compared to the samples based on 75% rice and 25% cowpea. In fact, the ash content of the 50% rice/50% cowpea and 75% rice/25% cowpea samples was significantly richer in minerals than that of rice alone (100% rice). A greater improvement in protein content was observed in formulations based on 50% rice and 50% cowpea, but also significant for those based on 75% rice and 25% cowpea. These contents ranged from 10.62±0.03% to 18.54±0.02%. Research by Sidibé et al [14] has shown that complementary food formulas for young children containing 25% cowpea and 75% rice

could have around 13% good-quality protein thanks to the contribution of the lysine contained in cowpea and the methionine provided by rice. The white cowpea (NB) sample and the 50% brown rice/50% white cowpea formulation showed the highest differences in crude fiber content ($p < 0.05$), ranging from 5.8% for the 50% brown rice/50% white cowpea formulation to 6.33% for the white cowpea (NB) variety. Analysis of the results revealed remarkably different fibre contents for the 50% rice and 50% cowpea formulations, ranging from 4.53 to 5.8%, and also for those based on 75% rice and 25% cowpea, compared with the three control rice varieties. In line with the work of AFSSA [27], the presence of fiber in foods intended for human consumption is favorable to the reduction of post-prandial glycemia and insulinemia. The carbohydrate contents of formulations based on 75% rice and 25% cowpea are closer to those of the three rice varieties, ranging from 71.60 to 75.58%, with statistically significant differences ($p < 0.05$) between samples. The 50% rice and 50% cowpea combinations had lower carbohydrate contents than the 75% rice and 25% cowpea formulations, with values ranging from 64.86 to 70.86%. This difference between the samples would be due to the proportion of cowpea added to rice, as cowpea and rice are different species whose main component is starch. Thus, the addition of a large quantity of cowpea not only reduced the total carbohydrate content, but also improved the fiber and protein content, both of good nutritional quality. Analysis of variance showed a significant difference in energy values between formulations based on 50% rice and 50% cowpea and those based on 75% rice and 25% cowpea, but differed for all combined samples (rice-cowpea). Also, the highest energy values were recorded for those combined with 75% rice and 25% cowpea. The high energy value for samples with 75% rice and 25% cowpea is due to the high carbohydrate content of rice. Energy in cereals and legumes comes mainly from carbohydrates, of which starch is the major component. This difference in macronutrient content differs from one region to another due to environmental and 116 climatic conditions, according to the study by N'guessan et al [28]. Thus, regular or moderate consumption of these combinations could help less active people or those suffering from metabolic diseases to have less energy-dense diets.

Table 3. Biochemical composition and energy value of processed food formulations

Differents food formulation	Humidity (g/100g)	Ash (g/100g)	Protein (g/100g)	Lipids (g/100g)	Fibers (g/100g)	Total carbohydrates (g/100g)	VE (Kcal/100g MS)
75BR–25WC	11.8±0.8^{a}	1.63±0.02^{c}	10.62±0.03^{d}	0.62±0.01^{c}	3.64±0.27^{b}	75.33±0.81^{b}	334.83±4.15^{b}
75BR–25RC	12.8±0.8^{a}	1.14±0.04^{d}	13.51±0.09^{c}	0.95±0.06^{d}	3.18±0.02^{b}	71.60±0.78^{c}	336.25±2.99^{b}
50BR–50WC	12 ±0.2^{a}	2.54±0.02^{a}	18.54±0.02^{a}	1.83±0.03^{a}	4.91±0.71^{a}	65.09±0.18^{e}	331.36±2.90^{bc}
50BR–50RC	12.7±0.3^{a}	1.87±0.12^{b}	17.41±0.02^{b}	1.01±0.11^{b}	5± 0.64^{ba}	67.01±0.27^{d}	326.74±2.12^{c}
75WR–25WC	12.5±0.5^{ab}	1.36±0.09^{c}	11.04±0.02^{b}	0.92±0.07^{c}	3.06±0.005^{b}	74.18±0.08^{c}	336.95±1.91^{a}
75WR–25RC	11.9±0.9^{ab}	1.22±0.03^{c}	10.45±0.02^{c}	0.88±0.02^{c}	3.39±0.15^{b}	75.58±0.87^{b}	338.12±3.10^{b}
50WR–50WC	11.3±0.1^{b}	1.97±0.08^{a}	14.67±0.14^{a}	1.19±0.02^{b}	4.53±0.42^{a}	70.86±0.45^{d}	334.75±1.94^{b}
50WR–50RC	12.9±0.3^{a}	1.77±0.02^{b}	14.8±0.14^{a}	1.55±0.03^{a}	5.01±0.01^{a}	68.97±0.36^{e}	329.02±1.35^{c}
75BrR–25WC	12.27±0.41^{bc}	1.17±0.02^{c}	12.64±0.02^{bc}	0.55±0.01^{d}	3.87±0.02^{c}	73.38±0.39^{a}	333.54±1.57^{b}
75BrR–25RC	12.2±0.2^{bc}	1.2±0.03^{c}	11.53±0.05^{c}	0.72±0.02^{c}	3.35±0.05^{d}	74.35±0.2^{a}	336.6±0.98^{b}
50BrR–50WC	14.13±0.61^{a}	2.05±0.03^{b}	16.94±4.06^{ab}	1.18±0.04^{a}	5.8±0.61^{b}	65.70±4.08^{b}	317.99±2.66^{c}
50BrR–50RC	13.53±0.15^{ab}	2.23±0.04^{a}	18.32±0.33^{a}	1.05±0.04^{b}	4.64±0.63^{a}	64.86±0.36^{b}	323.62±0.91^{c}

Note: BR: black rice; WR: white rice; BRr: brown rice; WC: white cowpea; RC: red cowpea

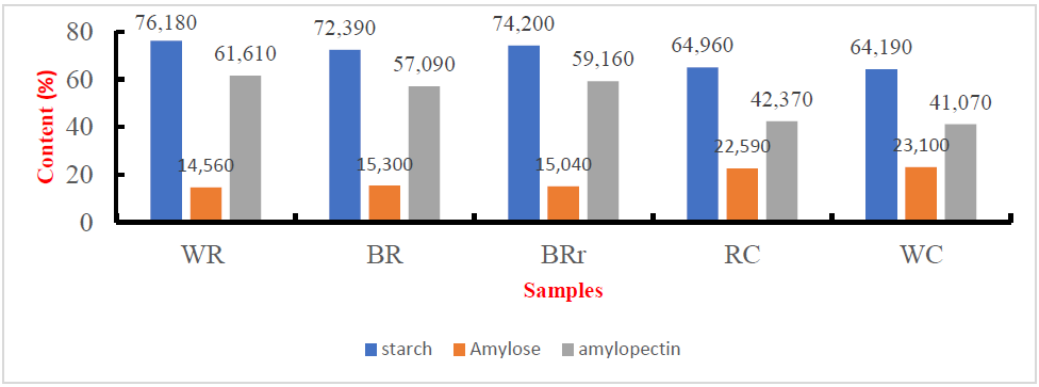

Figure 2. Starch, amylose and amylopectin contents of rice and cowpea varieties

3.2. Starch, Amylose and Amylopectin Contents of samples

3.2.1. Rice and Cowpea Varieties Samples

The starch, amylose and amylopectin contents of rice and cowpea varieties are shown in Figure 2. Amylose and amylopectin contents in rice and cowpea samples ranged from 14.56% to 23.1% and 41.07% to 61.18% respectively. The three rice varieties had the highest starch and amylopectin contents, ranging from 74.2 to 76.18% and 57.09 to 61.18% respectively, compared with the two cowpea varieties. The two cowpea varieties had starch and amylopectin values of 64.19% and 41.07% respectively for white cowpea and 64.96% and 42.37% for red cowpea. On the other hand, amylose levels are higher in cowpea

samples than in the three rice varieties. Amylose contents ranged from 14.56 to 23.10%. According to Massaux et al [29], this difference is due to the size and structure of the starch granules, their botanical origin and even their content. This difference could be justified by the type and variety of cereal used.

3.2.2. Food Formulations Samples Based on Rice and Cowpea Varieties

Figure 3 shows the different starch, amylose and amylopectin contents of formulations based on rice and cowpea varieties. Whatever the rice and cowpea variety, amylose contents were higher in the 50% rice and 50% cowpea formulations than in the 75% rice and 25% cowpea formulations followed by the three rice varieties. These contents ranged from 24.61 to 30.08%. Conversely, amylopectin levels are higher in formulations with 75% rice and 25% cowpea than in those with 50% rice and 50% cowpea. Conversely, starch and amylopectin contents are higher in formulations based on 75% rice and 25% cowpea and those based on 50% rice and 50% cowpea. These contents range from 76.18% to 69.09% and 61.61% to 44.43% starch and amylopectin respectively for all formulations (Figure 3 a, b, c). This difference could be explained by the type and variety of cereal used. In addition, the amylose and amylopectin contents in the 12 formulated recipes are a function of the type and ratio of cowpea to rice. The lower amylopectin content was observed in formulations with 50% rice and 50% cowpea, compared with those formulated with 75% rice and 25% cowpea. Also, the lower amylopectin content in these 50% rice and 50% cowpea formulations showed an increase in amylose content. In fact, most of the carbohydrates in cereals are in the form of starch, with a high proportion of amylopectin. According to Copeland et al [30], amylose and amylopectin are the main constituents of starch, representing 98-99% of the dry weight of granules.

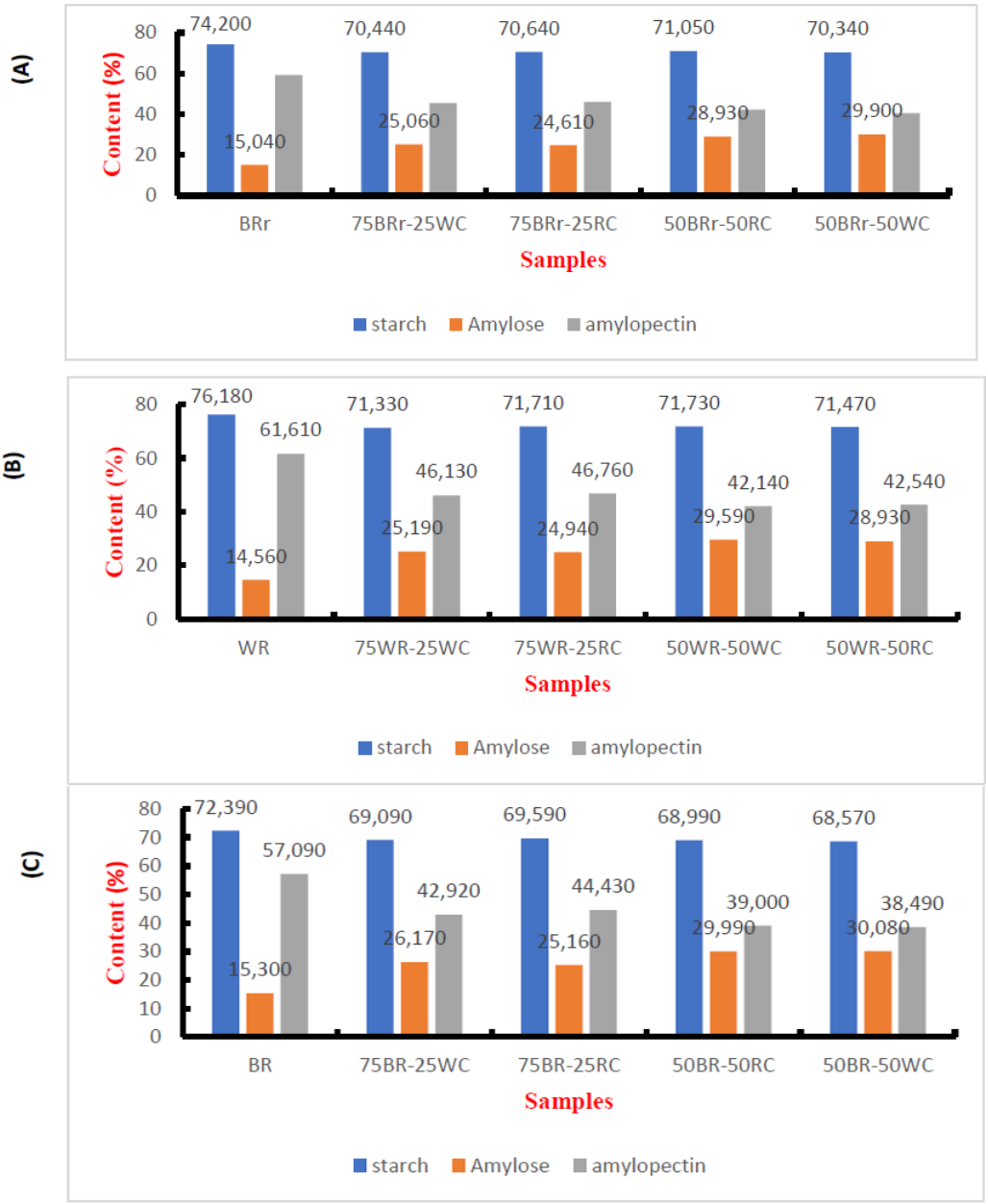

Figure 3. Starch, Amylose and Amylopectin Contents of food formulation based on brown rice and cowpea varieties (A), black rice and cowpea varieties(B) and white rice and cowpea varieties (C)

4. Conclusion

The results of the biochemical properties of the formulations developed (ash, proteins, lipids, fibers, starches, amyloses and amylopectins) showed that the contents of these compounds varied significantly according to the rate of cereal-legume combination, whatever the variety of cereal and legume. In general, the preparation of rice and cowpea-based recipes resulted in an increase in these nutrient compounds compared with individual rice consumption. Daily consumption of the cereal/legume pair would therefore be beneficial in correcting and/or preventing metabolic diseases, in particular type 2 diabetes. The study of the glycemic index will enable us to better understand the impact of these recipes on blood sugar levels, to help diabetics achieve their desired health goals.

List of Abbreviations

FAO = Food and Agriculture Organization of the United Nations;

MINADER = Ministry of Agriculture and Rural Development;

AFSSA = French Food Safety Agency;

AOAC = Association of Official Analytical Chemists

Ethics Approval and Consent to Participate

Not applicable.

Human and Anımal Rıghts

No animals/humans were used in the studies that are the basis of this research.

Consent for Publication

Not applicable.

Availability of Data and Materials

All the data and materials are included in this paper.

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Conflict of interest

The authors declare no conflicts of interest, financial or otherwise.

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