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Development of Pasta (Tagliatelle) from Composite Flours of Plantain, Cassava and Wheat

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Abstract

This study aimed to develop tagliatelle-type pasta using composite flours derived from plantain (*Musa paradisiaca*), cassava (*Manihot esculenta*) and wheat (*Triticum aestivum*), in order to enhance the value of local resources and reduce dependence on wheat imports. Flours from plantain (*Afoto* and *Agnrin* varieties) and cassava (*Bonoua* variety) were prepared, physicochemically and functionally characterised, and partially substituted for wheat flour. The results showed that increasing the incorporation of plantain and cassava flours led to a decrease in moisture content (12.96–8.63%), an increase in ash content (1.37–2.32%) and a generally low titratable acidity (0.067–0.112 g NaOH/100 g DM). Moreover, this substitution significantly improved water absorption capacity (254.82–309.20%), indicating better hydration of the starchy matrices. However, the dispersibility and swelling power (2.28–32.52 ge/g DM) of the composite flours decreased with higher levels of plantain and cassava. The resulting pasta exhibited acceptable cooking times (10–12 min) and controlled disintegration degree (13.76–17.23%), although higher than the control (9.99%). The *Afoto* variety provided a firmer texture compared with *Agnrin*. These findings confirm the technological feasibility and nutritional relevance of composite pasta based on local resources.

Keywords: Plantain; Cassava; Composite Flours; Pasta; Functional Properties.

1. Introduction

The growing demand for foods with high nutritional value derived from local resources is driving the rethinking of agri-food processing in tropical countries. In Côte d'Ivoire, plantain (*Musa paradisiaca*) plays a strategic role in both food security and the rural economy. It ranks as the fourth staple crop after yam, cassava and rice, with national production exceeding 2 million tonnes in 2019 [1]. With an average consumption estimated at 120 kg per capita, it is widely used in traditional dishes such as *foutou*, *foufou* and *aloco* [2].

However, plantain is a highly perishable fruit: it ripens rapidly, within five to nine days at ambient temperature, resulting in post-harvest losses of 30–40% [3]. These losses are mainly due to inadequate post-harvest practices, lack of storage and transport infrastructure, and enzymatic browning, which affects the visual and organoleptic quality of the product [4]. Thus, better valorisation of this resource is required to reduce waste and strengthen food sovereignty.

At the same time, pasta consumption is steadily increasing in Côte d'Ivoire, but production depends almost entirely on imported wheat flour. This economic dependency, coupled with the volatility of the international wheat market,

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increases the vulnerability of the local sector [5]. Furthermore, gluten sensitivity among some consumers has encouraged the development of gluten-free or low-gluten alternatives [6].

In this context, the use of locally available starch-rich flours such as plantain and cassava appears to be a sustainable and economically viable approach to diversify the food supply [7]; [8].

Recent studies on composite pasta formulations have shown that partial substitution of wheat with plantain or cassava flour improves fibre content, starch digestibility and textural stability [9] ; [10]. Incorporating these flours into local formulations could not only reduce import dependence but also create a food-processing value chain that adds value to Ivorian agricultural production.

Therefore, the present study aimed to develop tagliatelle-type pasta using composite flours of plantain, cassava and wheat, and to evaluate their physicochemical, functional and cooking properties. The overall objective was to propose a technologically viable, nutritionally beneficial and economically sustainable alternative that promotes local resources and national food security.

2. Materials and methods

2.1. Plant Material

The plant material (Figure 1) consisted of plantains (Musa paradisiaca), varieties *Afoto* and *Agnrin*, harvested at the green stage (stage 1) from the experimental station of the National Agronomic Research Centre (CNRA) in Azaguié (Côte d'Ivoire). Cassava roots (*Manihot esculenta* Crantz, *Bonoua* variety) and durum wheat semolina were purchased from the local market. After harvesting, the bunches of each plantain variety were placed in 50 kg jute sacks and transported to the Laboratory. A 25 kg portion from each sack was used as the experimental sample.

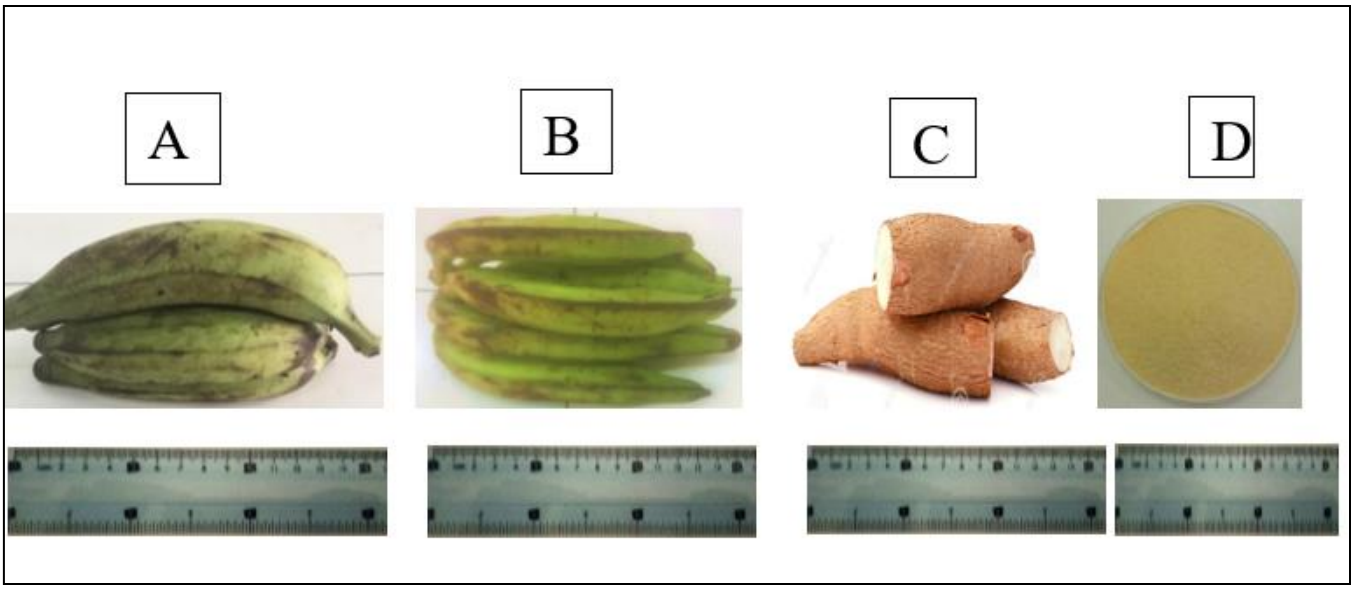


Figure 1 Plantains (*Afoto* – A, *Agnrin* – B), cassava roots (*Bonoua* – C) and durum wheat semolina flour (D) used in the production of composite flours

2.2. Preparation of Flours

Green plantains were washed with tap water, peeled and the ends removed. The pulps were soaked for 1 h in an anti-browning acetic acid solution, cut into chips and dried in a ventilated oven (BIOBASE, Shandong, China) at 45 °C for 24 h. The dried chips were then ground using a MOULINEX mixer (Normandy, France) and sieved through a 250 µm mesh (AFNOR sieve). Cassava roots were subjected to the same treatment: peeling, washing, slicing, drying at 45 °C for 24 h, grinding and sieving through 250 µm mesh. Durum wheat semolina was ground and sieved under the same conditions. All obtained flours were stored in opaque airtight containers until analysis.

2.3. Formulation of Composite Flours

Six composite flours formulations were developed: three based on the *Afoto* variety and three on the *Agnrin* variety, in addition to a 100% wheat control (Table 1). The incorporation ratios (plantain:cassava:wheat) were 42.5:42.5:15 (F1), 40:40:20 (F2) and 37.5:37.5:25 (F3) for each plantain variety. The mixtures were homogenised for 10 min using a paddle mixer and stored in sealed polyethylene bags at 4 °C.

Table 1 Composite Flours Formulations

INCORPORATION RATE (%)				
Formulations	*Afoto* Plantain Flour	*Agnrin* Plantain Flour	Cassava Flour	Wheat Flour
T	0	0	0	100
Af.F1	42.5	0	42.5	15
Af.F2	40	0	40	20
Af.F3	37.5	0	37.5	25
Ag.F1	0	42.5	42.5	15
Ag.F2	0	40	40	20
Ag.F3	0	37.5	37.5	25

T: Control (100% wheat flour). **Af.F1:** Formulation containing 42.5% Afoto plantain flour + 42.5% cassava flour + 15% wheat flour. **Af.F2 :** Formulation containing 40% Afoto plantain flour + 40% cassava flour + 20% wheat flour. **Af.F3 :** Formulation containing 37.5% Afoto plantain flour + 37.5% cassava flour + 25% wheat flour**. Ag.F1:** Formulation containing 42.5% Agnrin plantain flour + 42.5% cassava flour + 15% wheat flour. **Ag.F2**: Formulation containing 40% Agnrin plantain flour + 40% cassava flour + 20% wheat flour. **Ag.F3 :** Formulation containing 37.5% Agnrin plantain flour + 37.5% cassava flour + 25% wheat flour.

2.4. Physicochemical and Functional Analyses

Water absorption capacity (WAC) and wettability were determined according to the methods of [11] and [12], respectively, while dispersibility was assessed according to [13]. Ash, moisture and titratable acidity contents were analysed following [14] official methods.

2.5. Pasta Production and Technological Tests

Tagliatelle-type pasta was produced at pilot scale. Each composite flour formulation was hydrated with 32% distilled water, kneaded for 15 min, sheeted to 1.5 mm thickness, cut into 6 mm strips, and dried at 40 °C for 24 h.

2.6. Cooking Time

Cooking time was determined according to [15] with slight modifications. A 100 g pasta sample was boiled in 2 L of distilled water for 10–15 min. At one-minute intervals, a strand was pressed between two glass slides to assess the degree of cooking.

2.7. Swelling Power

Swelling Power tests followed the method of [16]. Flour suspensions (1% w/v) were heated in a water bath (50–95 °C) under constant agitation for 30 min, centrifuged (SIGMA 3-16P) at 4200 rpm for 15 min, and the pellet dried at 105 °C for 48 h. Swelling (G, ge/g DM) was calculated as:

$$\mathbf{G\ (ge/g\ MS)} = \frac{Mch - Mcs}{Mcs}$$

Where

Mch = mass of wet sediment (g);

Mcs = mass of oven-dried sediment (g).

2.8. Disintegration Degree of Cooked Pasta

The disintegration degree was evaluated according to an adaptation of [15] **Becila *et al.* (2023)**. Fifty mL of distilled water (25 °C) were added to cooked pasta in a beaker and stirred magnetically for six minutes. The supernatant was filtered through a 1000 µm sieve. A 10 mL aliquot was dried in a ventilated oven at 100 °C until constant weight. The dry extract (ES) was weighed and disintegration degree (DD) calculated as:

$$\mathbf{DD}(\%) = \frac{(\mathbf{ES} \times \mathbf{5} \times \mathbf{100}) \times \mathbf{100}}{\mathbf{10}\ (\mathbf{100} - \mathbf{H})}$$

Where

ES = dry extract (g) from 10 mL aliquot;

H = moisture content (%) of the pasta.

2.9. Statistical Analyses

All measurements were performed in triplicate and expressed as mean ± standard deviation. Data were analysed using STATISTICA 7.1 software. One-way ANOVA and Duncan's multiple range test were applied, with significance set at $p < 0.05$.

3. Results

3.1. Physicochemical Characteristics of Composite Flours

Data in Table 2 indicate that moisture content decreased significantly ($p < 0.05$) as the incorporation rate increased, with values ranging from 10.73 ± 2.29 to 8.98 ± 0.04% for *Afoto* and from 12.96 ± 1.69 to 8.63 ± 0.51% for *Agnrin*. Conversely, ash and titratable acidity increased with higher plantain substitution levels. Ash content varied from 1.37 ± 0.30 to 2.32 ± 0.32%, and titratable acidity from 0.067 ± 0.05 to 0.112 ± 0.05 g NaOH/100 g DM.

Table 2 Physicochemical characteristics of formulations

Parameter	Formulations						
	T	Af.F1	Af.F2	Af.F3	Ag.F1	Ag.F2	Ag.F3
Moisture (%)	13.04 ± 0.54^{d}	8.98 ± 0.04^{ab}	10.19 ± 0.8^{b}	10.73 ± 2.29^{b}	8.63 ±0.51^{a}	11.14 ± 1.64^{c}	12.96 ± 1.69^{d}
Ash (%)	0.87 ± 0.06^{a}	2.32 ± 0.32^{c}	2.07 ± 0.38^{c}	1.53 ± 0.08^{abc}	2.23 ± 0.23^{c}	1.85 ± 0.70^{bc}	1.37 ± 0.3^{ab}
Titratable acidity (g NaOH/100g MS)	0.045 ± 0.00^{a}	0.112 ± 0.05^{d}	0.090 ± 0.00^{c}	0.067 ± 0.05^{b}	0.112 ± 0.05^{d}	0.090 ± 0.00^{c}	0.067 ± 0.05^{b}

Means ± standard deviations with different letters in the same row differ significantly at the 5% level (Duncan's test).

T: Control (100% wheat flour). **Af.F1:** Formulation containing 42.5% *Afoto* plantain flour + 42.5% cassava flour + 15% wheat flour. **Af.F2:** Formulation containing 40% *Afoto* plantain flour + 40% cassava flour + 20% wheat flour. **Af.F3:** Formulation containing 37.5% *Afoto* plantain flour + 37.5% cassava flour + 25% wheat flour**. Ag.F1:** Formulation containing 42.5% *Agnrin* plantain flour + 42.5% cassava flour + 15% wheat flour. **Ag.F2**: Formulation containing 40% *Agnrin* plantain flour + 40% cassava flour + 20% wheat flour. **Ag.F3:** Formulation containing 37.5% *Agnrin* plantain flour + 37.5% cassava flour + 25% wheat flour.

3.2. Physico-functional Properties of Composite Flours

3.2.1. Wettability and Water Absorption Capacity (WAC)

As shown in Table 3, wettability increased significantly ($p < 0.05$) with higher plantain flour incorporation, from 52.00 ± 0.07 to 80.00 ± 0.03 min for Afoto and from 49.00 ± 0.01 to 74.00 ± 0.05 min for Agnrin, all higher than the control (39.00 ± 1 min). WAC also increased significantly ($p < 0.05$) from 254.82 ± 14.36 to 286.05 ± 3.47% for Afoto and from

268.01 ± 3.63 to 309.20 ± 16.92% for Agnrin. At equal substitution levels, Agnrin-based flours exhibited higher WAC than Afoto-based ones.

Table 3 Physico-functional characteristics of formulations

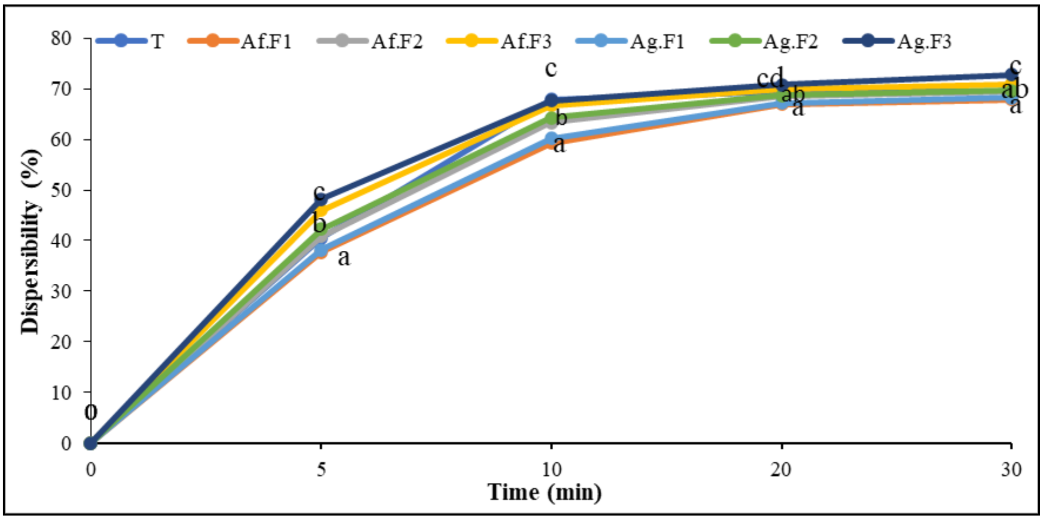
Parameter	Formulations						
	T	Af.F1	Af.F2	Af.F3	Ag.F1	Ag.F2	Ag.F3
Wettability (min)	39.00 ± 1[a]	80.00 ± 0.03[g]	60.00 ± 0.07[e]	52.00 ± 0.07[c]	74.00 ± 0.05[f]	55.00 ± 0.08[d]	49 ± 0.01[b]
WAC (%)	188.23 ± 2.88[a]	286.05 ± 3.47[e]	275.04 ± 6.85[d]	254.82 ± 14.36[b]	309.20 ± 16.92[g]	298.22 ± 11.83[f]	268.01 ± 3.63[c]

Means ± standard deviations with different letters in the same row differ significantly at the 5% level (Duncan's test).

T: Control (100% wheat flour). **Af.F1:** Formulation containing 42.5% *Afoto* plantain flour + 42.5% cassava flour + 15% wheat flour. **Af.F2:** Formulation containing 40% *Afoto* plantain flour + 40% cassava flour + 20% wheat flour. **Af.F3:** Formulation containing 37.5% *Afoto* plantain flour + 37.5% cassava flour + 25% wheat flour**. Ag.F1:** Formulation containing 42.5% *Agnrin* plantain flour + 42.5% cassava flour + 15% wheat flour. **Ag.F2**: Formulation containing 40% *Agnrin* plantain flour + 40% cassava flour + 20% wheat flour. **Ag.F3:** Formulation containing 37.5% *Agnrin* plantain flour + 37.5% cassava flour + 25% wheat flour.

3.3. Dispersibility

Figure 2 shows the variation in dispersibility over time. All composite flours exhibited a significant ($p < 0.05$) increase during the first 20 minutes, followed by a plateau between 20 and 30 minutes. Generally, formulations containing *Agnrin* flour were more dispersible than those with *Afoto* at equivalent substitution levels. Furthermore, flours with higher wheat proportions (T and F3) displayed slightly greater dispersibility than those richer in plantain flour (F1 and F2).

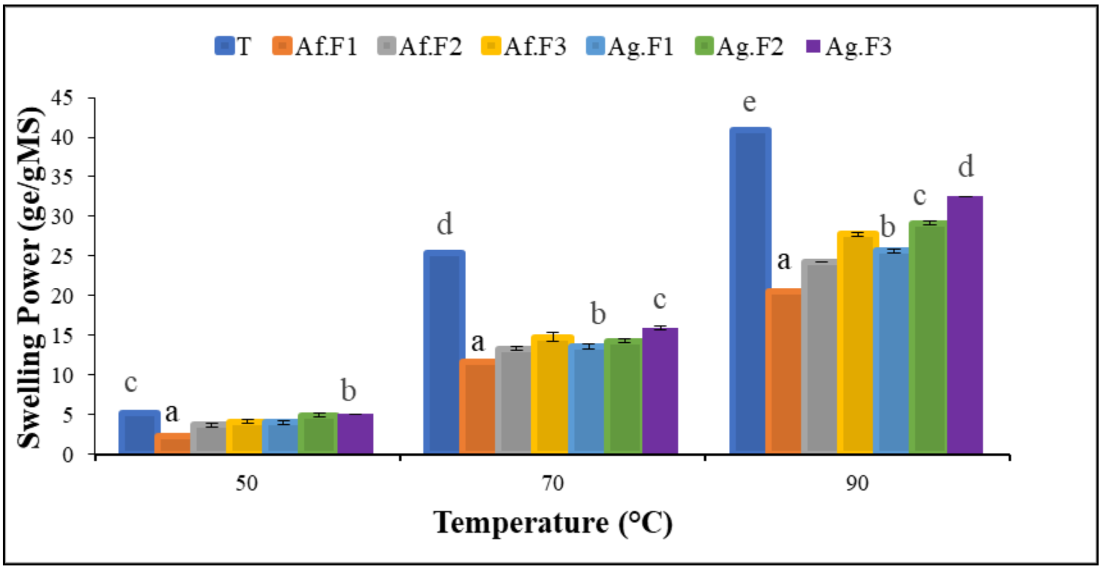


Means ± standard deviations with different letters differ significantly at the 5% level (Duncan's test).**T**: Control (100% wheat flour). **Af.F1:** Formulation containing 42.5% *Afoto* plantain flour + 42.5% cassava flour + 15% wheat flour. **Af.F2:** Formulation containing 40% *Afoto* plantain flour + 40% cassava flour + 20% wheat flour. **Af.F3:** Formulation containing 37.5% *Afoto* plantain flour + 37.5% cassava flour + 25% wheat flour**. Ag.F1:** Formulation containing 42.5% *Agnrin* plantain flour + 42.5% cassava flour + 15% wheat flour. **Ag.F2**: Formulation containing 40% *Agnrin* plantain flour + 40% cassava flour + 20% wheat flour. **Ag.F3:** Formulation containing 37.5% *Agnrin* plantain flour + 37.5% cassava flour + 25% wheat flour.

Figure 2 Dispersibility of composite flours as a function of time.

3.4. Swelling Power

As illustrated in Figure 3, swelling increased with temperature but decreased significantly ($p < 0.05$) with higher plantain incorporation. Values ranged from 2.28 ± 0.23 to 27.76 ± 0.74 ge/g DM for *Afoto* and from 3.98 ± 0.37 to 32.52 ± 0.91 ge/g DM for *Agnrin*. *Agnrin*-based flours consistently showed higher swelling than *Afoto*-based ones for the same incorporation level.



Means ± standard deviations with different letters differ significantly at the 5% level (Duncan's test).**T**: Control (100% wheat flour). **Af.F1:** Formulation containing 42.5% *Afoto* plantain flour + 42.5% cassava flour + 15% wheat flour. **Af.F2:** Formulation containing 40% *Afoto* plantain flour + 40% cassava flour + 20% wheat flour. **Af.F3:** Formulation containing 37.5% *Afoto* plantain flour + 37.5% cassava flour + 25% wheat flour. **Ag.F1:** Formulation containing 42.5% *Agnrin* plantain flour + 42.5% cassava flour + 15% wheat flour. **Ag.F2**: Formulation containing 40% *Agnrin* plantain flour + 40% cassava flour + 20% wheat flour. **Ag.F3:** Formulation containing 37.5% *Agnrin* plantain flour + 37.5% cassava flour + 25% wheat flour.

Figure 3 Variation of Swelling Power of composite flours as a function of temperature.

3.5. Appearance of Pasta

The obtained composite flours yielded stable pastes suitable for tagliatelle production (Figure 4). Increasing wheat flour percentage improved the appearance and texture of the pasta. Af.F3 and Ag.F3 exhibited the best cohesion, with Ag.F3 showing a colour closest to 100% wheat pasta.

3.6. Cooking Properties of Pasta

3.6.1. Disintegration Degree and Cooking Time

As reported in Table 4, the disintegration degree increased significantly ($p < 0.05$) with higher plantain levels, from 13.76 ± 0.25 to 15.28 ± 0.03 % for *Afoto* and from 14.40 ± 0.39 to 17.23 ± 0.19 % for *Agnrin*, all higher than the control (9.99 ± 0.12 %). Cooking times ranged from 10.00 ± 1.00 to 12.00 ± 1.00 min for both varieties, decreasing with higher plantain substitution. No significant difference was observed between *Afoto*- and *Agnrin*-based pasta ($p > 0.05$).

Table 4 Cooking characteristics of pasta

Parameter	**Formulations**						
	T	Af.F1	Af.F2	Af.F3	Ag.F1	Ag.F2	Ag.F3
Disintegration Degree (%)	9.99 ± 0.12^{a}	15.28 ± 0.03^{d}	14.72 ± 0.19^{c}	13.76 ± 0.25^{b}	17.23 ± 0.19^{e}	15.63 ± 0.69^{d}	14.40 ± 0.39^{c}
Cooking Time (min)	15.00 ± 1^{d}	10.00 ± 1^{a}	11.00 ± 1^{ab}	12.00 ± 1^{bc}	10.00 ± 1^{a}	11.00 ± 1^{ab}	12.00 ± 1^{bc}

*Means ± standard deviations with different letters in the same row differ significantly at the 5% level (Duncan's test).***T**: Control (100% wheat flour). **Af.F1:** Formulation containing 42.5% *Afoto* plantain flour + 42.5% cassava flour + 15% wheat flour. **Af.F2:** Formulation containing 40% *Afoto* plantain flour + 40% cassava flour + 20% wheat flour. **Af.F3:** Formulation containing 37.5% *Afoto* plantain flour + 37.5% cassava flour + 25% wheat flour. **Ag.F1:** Formulation containing 42.5% *Agnrin* plantain flour + 42.5% cassava flour + 15% wheat flour. **Ag.F2**: Formulation containing 40% *Agnrin* plantain flour + 40% cassava flour + 20% wheat flour.**Ag.F3:** Formulation containing 37.5% *Agnrin* plantain flour + 37.5% cassava flour + 25% wheat flour.

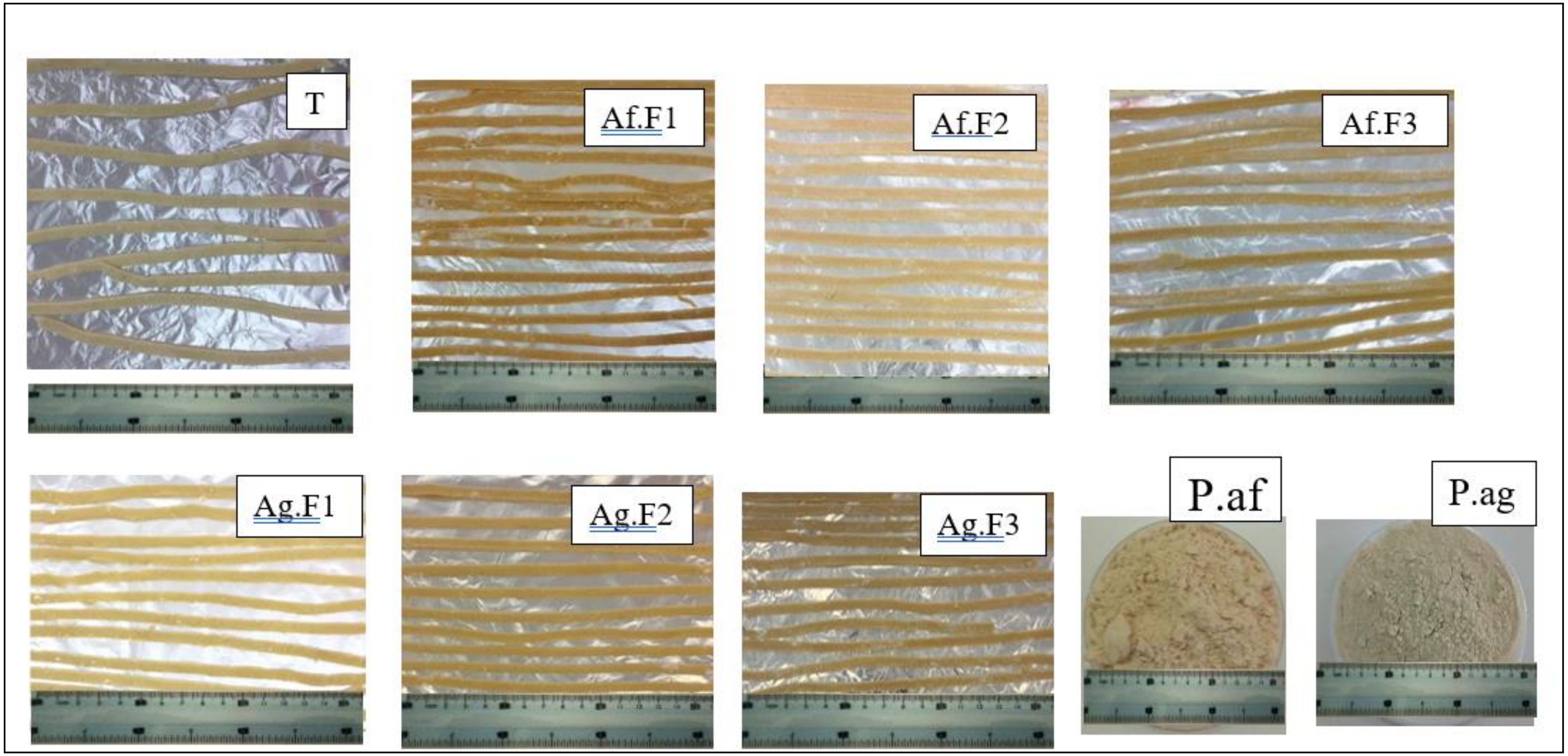


Figure 4 Tagliatelle-type pasta formulated from composite flours F1 to F3.

T: Control (100% wheat flour). **Af.F1:** Formulation containing 42.5% *Afoto* plantain flour + 42.5% cassava flour + 15% wheat flour. **Af.F2:** Formulation containing 40% *Afoto* plantain flour + 40% cassava flour + 20% wheat flour. **Af.F3:** Formulation containing 37.5% *Afoto* plantain flour + 37.5% cassava flour + 25% wheat flour**. Ag.F1:** Formulation containing 42.5% *Agnrin* plantain flour + 42.5% cassava flour + 15% wheat flour. **Ag.F2**: Formulation containing 40% *Agnrin* plantain flour + 40% cassava flour + 20% wheat flour. **Ag.F3:** Formulation containing 37.5% *Agnrin* plantain flour + 37.5% cassava flour + 25% wheat flour. **P.af**: *Afoto* plantain flour*;* **P.ag**: *Agnrin* plantain flour.

4. Discussion

The obtained results demonstrate that partial substitution of wheat flour with plantain and cassava flours significantly affects the physicochemical, functional, and technological properties of the produced pasta. Increasing local flour proportions improved water absorption capacity and swelling, while also modifying pasta texture and cooking behaviour. These findings agree with those of [7], who reported that gradual incorporation of plantain flour in gluten-free pasta enhances water retention and viscosity due to starch granule structure and amylose–amylopectin composition.

The recorded moisture contents (9–13%) were consistent with dry product storage standards [17], ensuring both microbiological stability and acceptable textural quality. The low titratable acidity values (0.067–0.112 g NaOH/100 g DM) indicate minimal fermentation and good oxidative stability. These results confirm that acetic acid treatment and moderate drying (45–50 °C) effectively preserve flour biochemical quality [18].

The high WAC values (254.8–309.2%) reflect the strong hydrophilic nature of the composite flours. According to [10], this property is associated with damaged starch content, fine granularity, and the presence of non-starch polysaccharides such as pectins and hemicelluloses, which enhance water retention in the matrix. Excessive water uptake, however, can make dough sticky, requiring adjustments in hydration during kneading. These trends align with [8], who observed increased WAC in plantain–cassava blends compared with pure wheat flour.

The initial rise in dispersibility reflects improved particle rehydration and gradual disaggregation, consistent with findings from studies on composite flours of taro and wheat [19]. The higher values for *Agnrin* may result from finer particle size and lower levels of hydrophobic compounds (lipids and proteins) that hinder water diffusion. Conversely, higher wheat proportions slightly improved dispersibility, probably due to gluten's structuring effect within the starch–protein network [20]. Good dispersibility is essential for uniform dough formation, smooth texture and consistent cooking performance.

The observed increase in swelling power with temperature results from progressive disruption of the starch crystalline structure and hydrogen bond breakdown during gelatinisation [21]. The lower swelling observed at higher plantain levels could be attributed to its high fibre and non-starch polysaccharide content, which restricts granule hydration [22]. In contrast, gluten presence in wheat improves water retention and network stability.

Reduced cooking time at higher plantain levels indicates faster starch gelatinisation, likely due to lower gluten content and looser granule structure of plantain and cassava flours [23]. Finer particles and a less compact matrix also favour water penetration and protein denaturation [24]. Conversely, higher wheat proportions promote longer cooking due to the viscoelastic gluten network [25].

The higher disintegration degrees of composite pasta compared to the control indicate reduced structural stability during cooking. This sensitivity could result from the weaker mechanical resistance of plantain and cassava starch granules and partial leaching of amylose and amylopectin [22]. Nevertheless, decreasing disintegration with increasing wheat proportion suggests improved starch–protein cohesion. The balance between local flours and wheat content is thus critical to ensure firm texture and good cooking stability.

Differences between *Afoto* and *Agnrin* varieties regarding WAC, swelling, dispersibility, disintegration degree and texture point to a strong varietal effect. *Afoto* provided greater cohesion, while *Agnrin* enhanced water uptake. These variations may stem from differences in starch granule size distribution and amylose/amylopectin ratios [26]. Further microstructural studies would help clarify how these traits influence pasta behaviour.

Economically and nutritionally, using local flours presents major advantages: it reduces dependence on imported wheat, strengthens food security and valorises local production. The resulting composite pasta may serve as an alternative source of complex carbohydrates and dietary fibre, with potential for moderate glycaemic index formulations [27]. Overall, these results support the industrial feasibility of partial wheat substitution with plantain and cassava flours, provided process parameters and raw material quality are optimised.

5. Conclusion

This study demonstrated the feasibility of producing tagliatelle-type pasta from composite flours combining plantain, cassava and wheat. The formulated flours exhibited favourable physicochemical and functional properties, including high water absorption capacity, low titratable acidity and good dispersibility. The resulting pasta showed acceptable cooking times, satisfactory texture and limited cooking losses. These findings open perspectives for industrial valorisation of local resources, contributing to reduced wheat import dependence and promoting a *"Made in Côte d'Ivoire"* pasta sector.

Future research should further investigate the microstructural and rheological characteristics of these flours, evaluate sensory and digestibility properties of the pasta, and explore additional treatments (fermentation, pre-gelatinisation, hydrocolloid enrichment) likely to improve product cohesion and stability.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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