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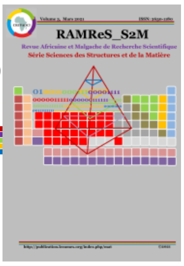

Improvement of IAC cassava semolina in *gari* (*Manihot esculenta* crantz): influence of the SIS semolina machine on the physico-chemical and sensory qualities of *gari*

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Abstract:

Gari is a traditional food that is highly valued and suitable for the nutrition of populations in sub-Saharan Africa and around the world. In order to improve production, 1500 grams of pre-processed cassava paste was semolinaed using a local SIS semolina machine operating in continuous mode. To achieve this, a diagnosis of the local production process was carried out using brainstorming and Failure Modes and Effects Analysis (FMEA) methods to identify residual non-conformities. In addition, the mass conservation equation was derived to determine the predictability of paste cake formation during grinding, in addition to the compressive forces applied during the paste dewatering. These determined factors are crucial for improved mechanical *garification*. Samples of pastes and semolina were subjected to physico-chemical and organoleptic analyses. The results indicated a significant hygienic risk, and the need to improve the determined mechanical parameters of the semolina, in particular the residual ferment content (optimal at 12% incorporation), the residual and ideal moisture content (optimal at 40-45% on a dry matter basis), and an optimal milling angle ranging from 35.1° to 37.5°. In conclusion, the optimum final moisture content for improved *garification* is (45.0 ± 0.2)% moisture content (dry matter). Sensory evaluations showed that the prepared *gari* semolina had favourable organoleptic characteristics compared to the control *gari*. Sensory attributes such as shape, size, and grain homogeneity were well accepted. This optimization of semolina parameters is significant as it minimizes human effort and improves the hygienic and market quality of semolina. The automation of semolina production in the *garification* process has the advantage of increasing economic performance and customer satisfaction within the *gari* industry.

Keywords: Cassava ; *Gari* ; Mechanical semolina ; Organoleptic characteristics ; Innovation.

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1 Introduction

Gari represents almost 70% of cassava processed for human consumption in West Africa [1]. It is almost the most consumed and sold starchy food product derived from cassava starch, second only to Ivorian *attiéké*. Nigeria consumes about 4,706,826 tons of *gari*, Benin 210,733 tons, Togo 159,059 tons, and Ghana 620,657 tons [2]. Despite its high consumption, traditional *gari* is a long labour-intensive process. Nevertheless, *gari* is characterized by mildly fermented and sour taste after pressing, semolina formation, and partial gelatinization during cooking.

Pressing and semolina production involve the manual crushing of the pressed cassava cake into fine, heterogeneous granules of varying consistency. The product is then cooked over an open flame until a sufficient degree of starch gelatinization is achieved. Throughout this process, the product is continuously stirred, a process known as *garification*. For optimum *garification,* it is essential to avoid the formation of lumps and excessive toasting during cooking, as these are generally undesirable in the final product. It is therefore essential to maintain the texture and homogeneity of the fine semolina, which is a quality criterion. The cooking-drying process is considered a crucial step in the production of desirable *gari* semolina in terms of color, particle size, and swelling power, as emphasized by [3, 4] and confirmed by [5]. The resulting *gari* can be consumed by diluting it in water or by pre-cooking it, often served with a preferred sauce, either directly or indirectly. Its widespread consumption is attributed to its relatively long shelf life and ease of preparation. However, the traditional production of *gari*, which is done manually by several people, is tedious and exhausting for the producers [6, 7]. The traditional processing method varies from region to region and has been well documented and described by several authors, including [6, 8, 9].

Today, there are several varieties of *gari*, including "*gari Sohoui*", "*gari Ahayoé*" and "*gari Sohia*" [10]. These *gari* varieties differ in their various textural, physico-chemical, nutritional and sensory qualities. Sensory quality in *gari* generally refers to the size of the grains, which should be fine and uniform in colour, slightly acidic, and have good storage and cooking properties [11, 12]. Recently studies focused on introducing a semi-industrial semolina machine (SIS), primarily for producing *attiéké* [13-15]. However, introducing such equipment into semolina processing step could provide a significant advantage for producers seeking technological innovation. Laboratory experiments with this technology suggest that fine semolina production from pressed cassava cake remains a crucial step that significantly influences the sensory quality of both *gari* and *attiéké*. Furthermore, the physico-chemical quality of *gari* could be further improved through control of the mechanical semolina process, leading to standardized production. This control could reduce hygienic (microbiological) and market (textural) risks associated with *gari* production, similar to extrusion-semolina. Physical risks and market degradation due to foreign bodies can greatly affect the quality of *gari* [12, 16] and customer satisfaction. In general, manual semolina production involves the use of a wooden sieve with varying mesh sizes and manual semolina production using utensils. This process is uncontrolled, time consuming, energy intensive and relies heavily on the experience of the operator. In order to contribute to the improvement of the physico-chemical and sensory qualities of *gari* during semolina production, factors influencing the textural quality of the semi-industrial semolina machine (SIS) were previously studied in the context of *attiéké* [15], and are now revisited in this study for *gari* production. The general objective is to integrate the SIS machine into *gari* production by enhancing the parameters that influence the sensory quality of *gari*. Specifically:

- To diagnose discrepancies in the current local *gari* semolina production process.
- To determine the optimum semolina factors using the integrated SIS.
- To define the sensory acceptability profile of the resulting *gari* semolina.

Do factors such as spontaneous fermentation, residual moisture content, pre-pressed paste, sieving of semolina, and sieving operations influence the textural quality of granules and by extension, the textural quality of *Gari* which has a whitish texture and fine particle size is highly regarded for its superior sensory quality? The aim is to investigate the influence of mechanical milling on the physico-chemical and sensory characteristics of *gari*. In other words, can the control of semi-automatic mechanical granulation of grated cassava paste lead to *gari* semolina of acceptable quality?

2 Materials et methods

2.1 Tuberous cassava roots

The plant raw material consists mainly of mature, fresh and healthy tuberous cassava roots namely *Improved African Cassava* (IAC) variety (*Manihot Esculenta* CRANTZ). It was collected locally at the production site. It was used for the production of local *gari* semolina.

2.2 Diagnosis to improve non-conformities

A compliance checklist was designed and used to diagnose the practices involved in the production of *gari* semolina. It was used to identify non-conformities according to [17]. In addition, the brainstorming method [18] was used to list hazards and classify them according to the 5 M (Material, Machine, Man power, Medium, Methods). Furthermore, the Failure Modes and Effects Analysis (FMEA) method [19] was used to assess residual risks requiring improvement in the semolina production process for enhanced *garification*. The assessment of significant risks using this method of analyzing failure modes, their effects and their criticality included the stages of hazard identification, assessment, and appropriate control measures. The levels of severity and frequency of damage occurrence in the criticality matrix (see Table 1) were used to assess the elimination or reduction (acceptable, moderate, or unacceptable) of the risk for their control.

Table 1
Risk Criticality Matrix.

		Factors for combination			
Severity (S)	**4** Critical	4	8	12	16
	3 Major	3	6	9	12
	2 Significant	2	4	6	8
	1 Minor	1	2	3	4
Criticality (S x P)		**1** Unlikely	**2** Very low	**3** Possible	**4** Frequent
		Probability of damage (P)			

Criticality (C) is the product of severity (S) and probability of damage (P). A criticality equal to or greater than 8 is considered critical (unacceptable risks🟥); a criticality between 3 and 6 is considered moderately critical (moderate risks🟨); a criticality less than or equal to 2 is considered mildly critical (acceptable risks🟩). The control measures identified for each critical hazard are then evaluated to determine improvement factors.

2.3 Final moisture content procedure

The dehydration process of cassava mash for semolina production followed to the methodology outlined by [15]. In brief, the compressive force (P) applied to the paste mass (m) corresponds to the rheological response of the paste under compression stress. This results in a cohesive mass, referred to as “paste cake” and the expulsion of liquid phase, as shown in figure 1. Finally, for any given initial paste mass taken, a differential mass conservation equation (m, w) can be applied as shown in figure 1.

The theoretical (Vw) and experimental (V) volume of cassava juice discarded values were in agreement at 1%. The relative error (E), both theoretical and practical, was determined according to the following equations:

$$E(\%) = (V_w - V) \times 100/V \qquad (1)$$

$$E(\%) = \frac{100}{p}\sum_{i=1}^{p}\left|\frac{V_w - V}{V}\right| \qquad (2)$$

The resulting paste was then crushed to 1 mm, untangled, and fed into the semi-industrial semolina machine.

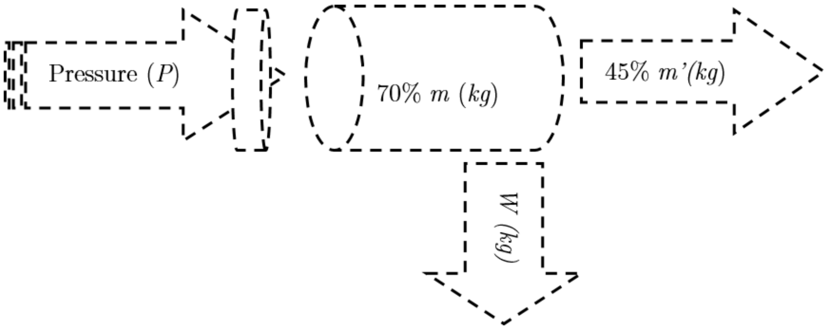

Fig. 1. Conservation relationship between mass and discarded volume of paste (*W* is the mass of cassava juice discarded, *m* is the initial mass, *m'* is the final mass).

2.4 Semolina grinding process

The semolina levels correspond to the SIS inclination, which allows the production of semolina with different shapes and sizes. This results in variations or angles (α) calculated according to the following equation:

$$\alpha = 45+(x_i/91) \qquad (3)$$

x_i is the seeder adjustment slope of the SIS semolina machine. Twenty-five batches of 1500 g of grated cassava paste were semolinaed at different angles of inclination. The particle size was determined in triplicate using the method of [20]. Sieving rejects (R) were calculated from the particle size distribution using the following equation:

$$R(\%) = \frac{P_t+G}{P_m} \times 100 \qquad (4)$$

G is the powder ($\varphi \leq 0.160$ mm), P_t is the total weight of grains and P_m is the weight of grains in sieve. In general, the size of the semolina varies according to the angle inclination of the SIS machine.

2.4.1 Physico-chemical analyses

Physico-chemical analyses were carried out according to established standard procedures. Ash content was determined by combustion of the samples at 550 °C for 24 hours according to the guidelines of [21]. Fat content was extracted by hexane reflux extraction using a Soxhlet apparatus, as described in [22]. Sugar extraction was performed according to the method described in [23]. Total sugars were quantified using the phenol and concentrated sulfuric acid method, as described by [24]. Total carbohydrates were determined according to [25]. Starch content was calculated as the difference between the percentages of total carbohydrates and total sugars. Reducing sugars were determined using 3,5-dinitrosalicylic acid (DNS) according to [26]. Moisture content was determined by desiccation at 105°C for 24 hours according to [27]. Protein content was determined by total nitrogen analysis according to [28]. The energy value (kilocalories per 100 g of dry matter) was calculated in relation to the dry matter (DM) according to [29]. The cellulose content was determined according to [30]. Lastly, pH and total acidity of the samples were determined according to method of [31] and [32], respectively. All analyses were performed in triplicate to ensure accuracy and consistency.

2.4.2 Sensory evaluation procedure

The method described by [32] was used to establish the sensory evaluation profile. The methodology proposed by [33] was used to characterize the organoleptic properties of the *gari* semolina samples, based on the descriptive terminology introduced by [34]. In practice, a total of twenty-five *gari* semolina samples were triple evaluated by a panel of 12 individuals, who had undergone prior training to effectively articulate the attributes of *gari*. To achieve this, one hundred grams of coded fresh and cooked *gari* semolina samples, distributed in sets of three, were presented to the panelists. For each *gari* sample tasted, the panelists rated the organoleptic charac-teristics or perceived attributes. Each panelist's performance was rated on a five-point scale, taking into account the reliability of their quantitative responses.

2.5 Statistical analyses

Statistical were carried out using Minitab software (1998) with a significance level of 5%. Analysis of variance (ANOVA) was used, followed by Duncan's test for comparison of means. For the sensory evaluation, the statistical decision of table provided by [34] was used to evaluate perceived differences between the *gari* semolina samples, with a significance threshold of 5%.

3 Results and discussion

3.1 Diagnosis of the traditional *gari* semolina production process using FEMA analysis

The Ishikawa diagram succinctly presents the residual non-conformities within the traditional *gari* production process. It is noteworthy that the process exhibits non-conformities in each of the elements comprising the 5 M (Materials, Machinery, Methods, Manpower, and Medium), implying an urgent need for process improvement. In particular, the semolina production process and its associated parameters require attention. With regard to these non-conformities affecting semolina production, the following can be described.

Material: Variability due to seasonality of IAC variety; Fluctuating moisture content of cassava; Observation of multiple physical forms of cassava.

Machine: Use of poorly designed wooden utensils, such as wooden graters, sieves, and the SIS semolina separator.

Methods: Incorrect settings of semolina production parameters, including sub-optimal sifting and limited disintegration of the paste; Congestion problems during filling of the paste into the cylinder drum and transfer via a pallet; unmarked alignment errors at certain angles; The configuration of air valves contributing to air pressure discrepancies during semolina production.

Manpower and Medium: A primary non-conformity relates to the qualifications of the operators; General hygiene concerns involving the 5 M.

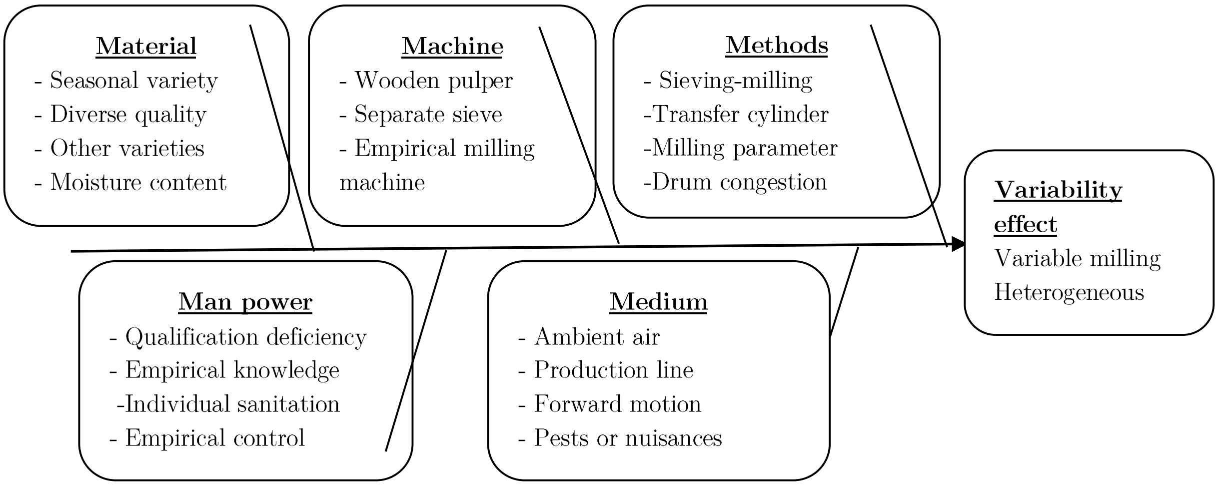

Fig. 2. Ishikawa diagram of residual non-conformities in the traditional *gari* production process.

Table 2 shows the variability effects observed in the production of *gari* semolina, assessed with the Failure Modes and Effects Analysis (FMEA) procedure [35]. The residual risks evaluation shows that the criticality is high, with a rating of 12. This implies an unacceptable risk due to several factors related to the pulping and milling methods used. These factors include the level of amount of fermented paste added, the type of force used and the initial moisture content of the cassava.

Table 2
Variability effects observed in *gari* semolina process, assessed using the FMEA.

Semolina process steps	Hazard /causes	Potential risks/consequences	Evaluation			Control measures /actions
			S	P	C	
Cassava reception	**Material** Non-targeted variety *IAC* of various sizes Other varieties Variable moisture content	Mixing between local varieties: *Yacé*, *Yavo* Variable yield during production Multitude of varieties with varying toxicity	3	3	9	Use of locally suitable materials followed by specifications (Good Manufacturing Practices, GMP)
Peeling-Washing-Cutting-Milling-fermentation-pressing	**Machinery** Wooden grater Transfer cylinder Manual adjustment Opening hopper	Inappropriate multiform wooden or metal equipment SIS semolina separator for *attiéké* Diversified equipment	2	1	2	GMP and Hygiene of Usual Equipment Suitable for Stainless Steel or Galvanized (GMP/H)
Grating-Granulation/ Semolina Production and Roasting of *Gari*	**Methods** Limited grating Transfer cylinder and congestion Pre-separation detangling on a separate manual sieve Manual adjustment and calibration Pressing/semolina melding force	Variability in shape, texture, and granule size Dependence on and variation in factors such as fermentation, pressure, angle, and moisture content Empirical control Mass uptake of paste or granules	4	3	12	Control or optimization of tilting factors and grating-*garification* force Control of pre-drying after squeezing, fermentation content, and residual moisture content (Critical Control Points, CCP)
Controlling Operators	**Man power** Unqualified individual Empirical knowledge individual sanitation	Empirical qualification Hygienic risks Empirical competency	2	3	6	Training and operational qualification of personnel (Training in Good Practices/Hygiene) Transition to operational mastery
Environment of Production (medium)	Ambient air Production line Forward flow Pests Facility hygiene	Presence of pests, dust Presence of impurities and foreign bodies Cross-contamination	1	2	2	Pest protection and Personal Protective Equipment (PPE) Construction of sheds or mechanical equipment operating areas under control (Good Manufacturing Practices/Hygiene)

C: Criticality; S: Severity; P: Probability of damage.

Conversely, at the material and labor levels, the criticality ratings are 6 and 9, indicating a moderate risk. However, at the equipment and labor levels, the risk is rated as 2, which is an acceptable level. This means that it is possible to implement a simple practice that could help improve *gari* production.

3.2 Control of the final moisture content of the dough for semolina production

The dehydrated dough cake for semolina production is ideally obtained during the pressing of fermented cassava dough, prior to semolina production. Optimal dehydration of the pressed cake, corresponding to a predetermined final moisture content of 45% on a dry basis of the material, is achieved when the pressing step is controlled. The differential equation derived from the conservation of mass is determined. The theoretical volume (Vw) corresponding to the reduction of the water content of the pulp from 70% to 45% (dry weight) gives the final mass (w, kg) of the cassava juice to be removed. The volume in m^3 of juice removed was deducted by taking into account the mass density (ρ, kg/m^3) of the dough. For any type of mass, such as 1500 g of grated IAC cassava, with an initial content of 0.7 ± 0.1 m^3 (70%, kg), the optimum final content is either 0.4 ± 0.1 m^3 (45%, kg), 0.4 ± 0.1 m^3 (50%, kg), or 0.4 ± 0.1 m^3 (51%, kg), and so on. This gives a mercury extract equal to W (kg). These results confirm those of [14], who showed that these values are 0.375 ± 0.10 m^3 (52%, kg) and 0.361 ± 0.10 m^3 (53%, kg) for *attiéké*. These data are 100% reproducible and reliable for the control of dehydration, regardless of the type of cassava dough used, provided that the initial content (% Hi) is known. It should be noted however that the inoculation rate (12%) and fermentation duration (12 hours) influence the pressure (p) exerted on the dough mass (m), which varies according to the equipment used. The change in volume of the pair (m, w) during pressing is showed in figure 3.

It is observed that regardless of initial mass and the conditions under which cassava paste is fermented, the mechanical action (N/m^2) influences the final paste cake. Consequently, it is observed that dehydration time increases proportionally with the volume of juice expelled. The physico-chemical composition is influenced by the pressing force applied. In particular, starting from an initial moisture content of 70%, as the pressing force increased (ranging from 6 to 7.5×10^5 N/m^2) the moisture content required for semolina production is ideally reached at 43.7%. As a result, the starch content decreases from 87.2% to 77.6%, a slight decrease that is ideal for good gelatinization. The gelatinization observed during cooking is attributed to the cooking temperature (i.e., 100°C) of the *gari* semolina, resulting in dextrinization, a significant increase in sugar content of about 1.01%. Hydrogen cyanide and carbohydrate contents vary in pressed paste and the resulting *gari* (Table 3). The observed variations decrease significantly depending of the physico-chemical parameters monitored before, during and after the semolina production process. This is due to fermentation, pressing, semolina production and cooking, which are all crucial steps in *gari* production. For example, an initially high hydrocyanic acid content, of about 55%, decreases to reach 0.09±0.01%, an ideal value for product consumption [36]. However, excessive pressing beyond the threshold (6.58 kN) renders semolina production unacceptable for *gari* production. This results in difficulties in producing *gari* semolina with acceptable physico-chemical and textural characteristics. Others results relating to proteins, fats, ash content, reducing sugars, and energy values are given in table 3.

In summary, pressing force significantly affects the moisture content, starch content, hydrogen cyanide content and residual sugar content of cassava paste as shown in table 3.

3.3 Particle size of *gari* semolina in relation to semolina machine deviation

The figure 4A highlights the particles size according to the semolina SIS inclination. Obviously, the semolina concentration falls within the range of 2 to 0.4 µm for all semolina angle deviation: 36.7; 36.3; 35.9 and 35.1, compared to the traditional standard. Experimentally, when the semolina is successively inclined at 37.5; 37.1 and 36.7 degrees, the semolina rejection, which accounts for 99% (in average size), ranges from 0.2 mm to 63 µm for fresh *gari* semolina. This observation holds true for cooked *gari* semolina, as showed in figure 4B.

Figure 4B shows the size distribution according to the inclination of the SIS machine. It is observed that when the semolina machine is successively inclined at 36.3; 35.9 and 35.5 degrees, it was found that the semolina rejection, which accounted for 99%, was within the size range of 0.4 mm to 63 µm for fresh semolina and between 0.2 mm to 63 µm for cooked semolina or *gari*. Notably, the variation in semolina size extends up to 0.200±0.001 mm, which is not significantly different from the control (traditional *gari* semolina).

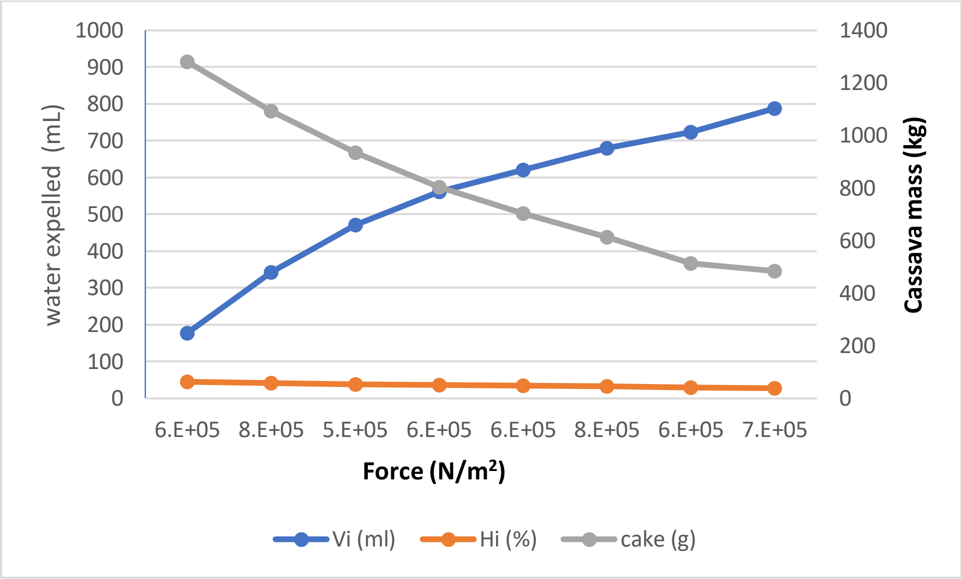

Fig. 3. Volume change of the pair (m, w) during pressing, water expulsion and conservation of mass.

Table 3

Pressing effect on the physico-chemical characteristics of dough and the *gari*.

Parameters	Cassava sample (g)		
	Pressed paste	Fresh semolina	*Gari* semolina
Moisture (%)	68.40±0.05a	45.7±0.2b	5.20±0.05c
Total sugar (%)	1.88±0.02a	1.88±0.02a	1.01±0.01a
Starch (%)	87±2a	75.2±0.1b	77.60±0.08c
Carbohydrate (%)	40.20±0.05a	52.00±0.05a	87.2±0.1b
HCN (%)	55.40±0.02a	10.30±0.01b	0.09±0.00c
pH	5.90±0.07a	3.84±0.05b	4.24±0.05b
Acidity (meq/100g ms)	9.7±0.5a	6.7±0.5b	6.7±0.5b
Proteins (%)	1.98±0.01a	0.87±0.01a	2.27±0.02b
Fat	2.80±0.01a	0.79±0.01b	1.48±0.02b
Ash (%)	0.38±0.01a	0.48±0.01a	0.81±0.01a
Reducing sugar (%)	1.59±0.02a	2.96±0.03b	2.7±0.1b
Energy Value (kcal)	193.3±0.0a	193.9±0.8a	371.1±0.3b

Mean values ± standard deviation of replication analysis, values followed by the same letter in a row are not significantly different at $p < 0.05$.

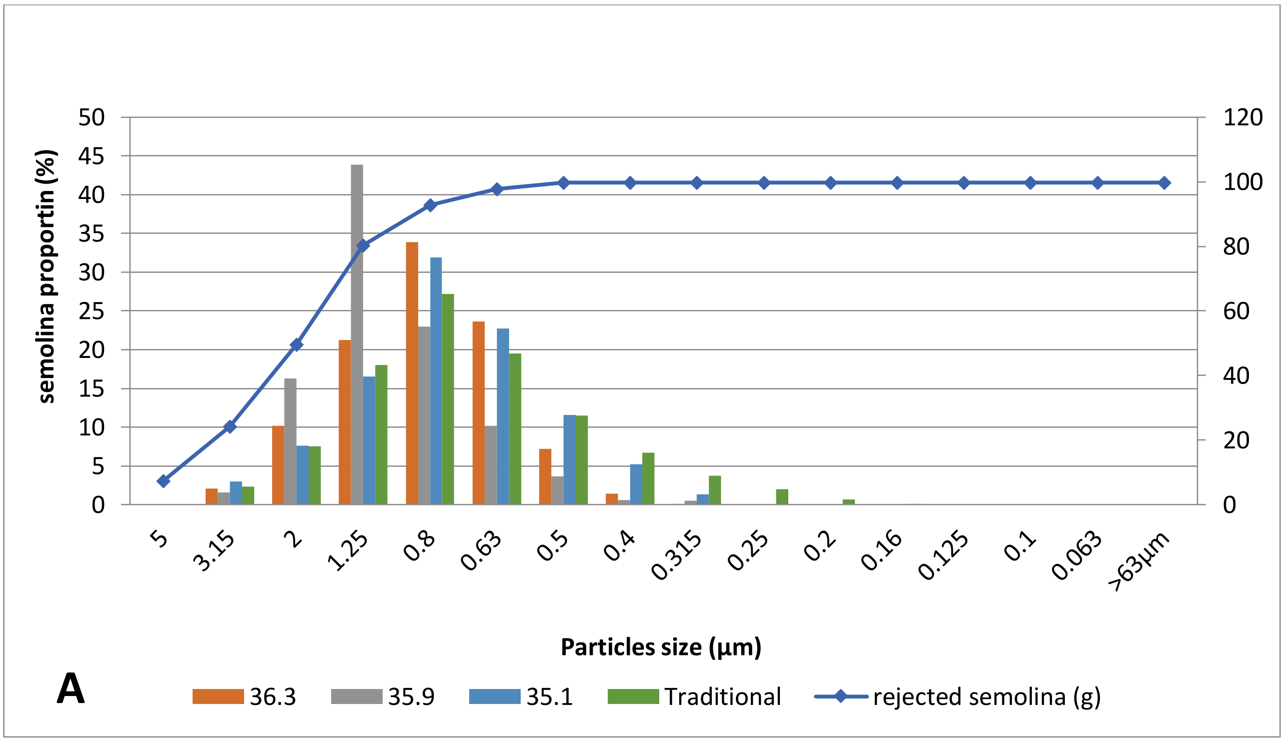

Fig. 4A. Particles size distribution based on semolina SIS inclination.

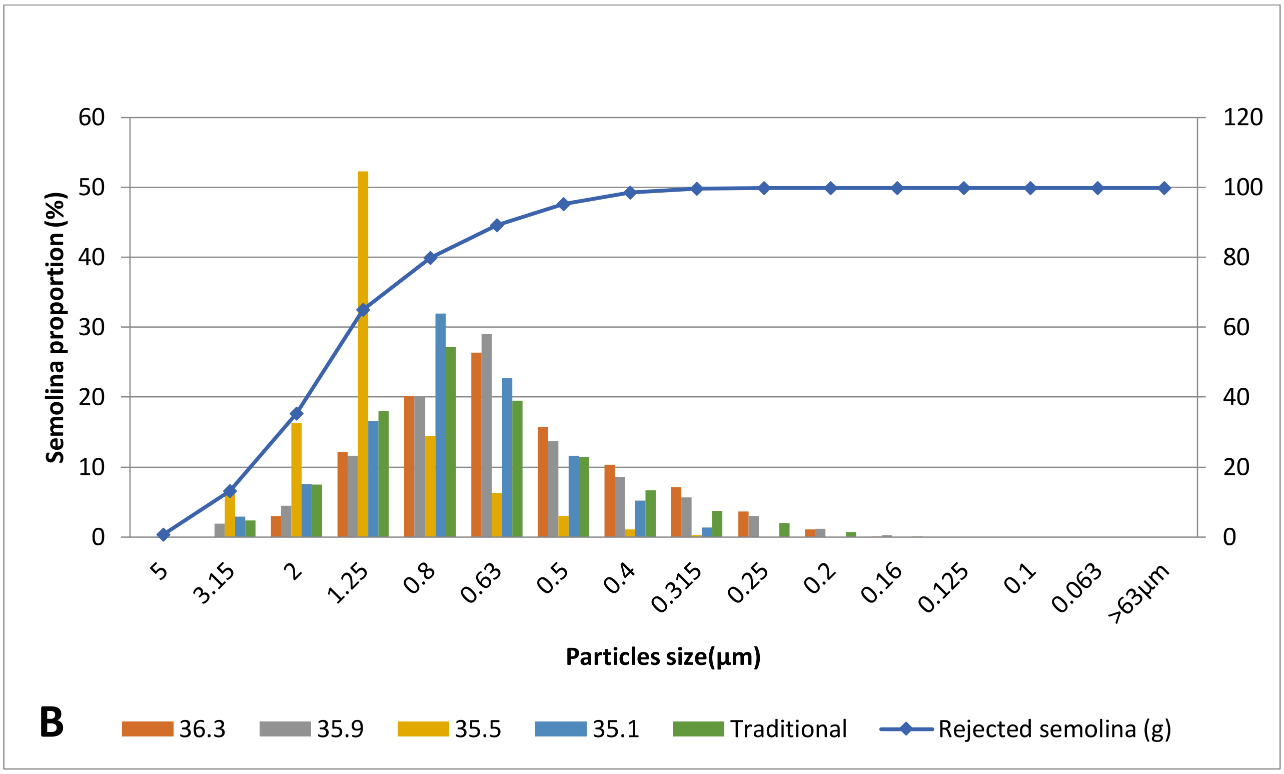

Fig. 4B. Particle size distribution according to the inclination of the SIS machine.

A significant proportion of semolina rejection (99%) was also observed at the inclination angle of 35.1°. The size measured ranged from 0.315 mm to 63 µm and from 0.2 mm to 63 µm for both fresh and cooked semolina (or *gari*), respectively. This is illustrated in figures 4A and 4B, which show the distribution of sieve rejects based on semolina inclination. Outside these ideal inclinations for *gari* production, semolina obtained at inclination angles of 26.8° to 32.0° showed coarse sieve rejects, with corresponding semolina sizes ranging from 0.8 to 5 mm in diameter.

In conclusion, the required size to obtain semolina comparable to traditional *gari* was achieved when the semolina was inclined between 37.5° and 35.1°. However, angles between 35.1° and 32.5° also produced semolina sizes comparable to traditional semolina. The different semolina samples obtained were subjected to a sensory evaluation.

3.4 Evaluation of the sensory profile of different types of *gari* semolina

The results of general sensory tests (Table 4) confirm that both fresh and cooked *gari* semolinas are well known products or perceived by tasters who could clearly distinguish between the different *gari*s presented and the traditional standard (*Gari*_tra).

As a result, *gari* semolina is firmly established in dietary habits of the population. In fact, it was observed that 100% of tasters could make a significant distinction between the control semolinas (*Gari*_tra) and the *gari*-25 semolinas (see Tables 4a and 4b). However, this difference is not statistically significant.

Semolina from *gari*-25 differed significantly from the traditional semolina (*Gari*_tra) and also from *gari*_1-3; *gari*_4; *gari*_5; *gari*_6 and *gari*_7. This can be attributed to the presence of coarse grains resulting from a low semolina inclination. Furthermore, the semolinas from *gari*_1-3; *gari*_4; *gari*_5; *gari*_6 and *gari*_7 showed the same grain size homogeneity.

The different observed are not statistically significant. For example, in terms of texture, the descriptive score was 3.10±0.01, with an exception of the semolina obtained between angles 26.8 and 32.0, which were rated at level 1 (Table 4). The overall sensation of *gari* characteristics was also assessed with the addition of mineral water (AWA, CI) in Table 4b, which includes evaluations of overall appreciation, color, roundness, swelling, and final flavor.

The results of the general sensory evaluation showed that *gari*_25 was the least favored by the tasters. This is due to its composition of coarse semolinas obtained after inclining the semouleur between 25 and 32 degrees. For example, in terms of overall flavor, the score was 2.60±0.01. This score differed from all the scores given to the tested cooked semolinas or *gari*s, which averaged 3.00±0.01. In addition, a consistent trend of rejection was observed by all the tasters for all the other parameters studied. These ratings were noticeably lower than the rating given to the *gari*s (*gari*_1-3; *gari*_4; *gari*_5; *gari*_6 and *gari*_7). Thus, scores were 1.50 ± 0.01 for “stickiness-water”, 2.00±0.01 for “fibrous-water” and 2.70±0.01 for “taste-water”. Finally, the hedonic test allowed the creation of an ideal semolina profile with a panel of 12 judges, the general evaluation of which is presented in figure 5. This figure shows the sensory profile of the scores assigned to the different types of semolinas by the panel (N=12). This allowed the creation of a sensory profile for *gari* semolinas.

Table 4a

Sensory evaluation of different types of *gari* semolina.

Sample	General Aspect				Taste Persistence			Feeling	
	Visual	Odour	Texture	Taste	Retaste	Aspect	Sniff	In mouth	General
*Gari*_1-3	3.00 ±0.01a	2.70 ±0.01a	3.00 ±0.01a	3.00 ±0.01a	3.00 ±0.01a	3.30 ±0.01a	3.20 ±0.01a	3.30 ±0.01a	12.40 ±0.01a,b
*Gari*_4	2.80 ±0.01a	2.90 ±0.01a	3.10 ±0.01a	3.20 ±0.01a	3.40 ±0.01a	3.30 ±0.01a	3.00 ±0.01a	3.40 ±0.01a	13.20 ±0.01a,b
*Gari*_5	2.60 ±0.01a	2.80 ±0.01a	2.70 ±0.01a	2.80 ±0.01a	3.00 ±0.01a	2.70 ±0.01a	2.80 ±0.01a	2.80 ±0.01a	11.30 ±0.01a,b
*Gari*_6	3.10 ±0.01a	3.10 ±0.01a	3.40 ±0.01a	3.20 ±0.01a	4.90 ±0.01a	3.30 ±0.01a	3.10 ±0.01a	3.20 ±0.01a	13.00 ±0.01a,b
*Gari*_7	3.40 ±0.01a	3.30 ±0.01a	3.10 ±0.01a	3.40 ±0.01a	4.70 ±0.01a	3.70 ±0.01a	3.30 ±0.01a	3.30 ±0.01a	13.90 ±0.01a,b
*Gari*_25*	2.3 ±0.1b	2.6 ±0.1b	2.30 ±0.01b	2.20 ±0.01b	2.40 ±0.01b	2.00 ±0.01b	2.30 ±0.01b	2.30 ±0.01b	8.90 ±0.01a,b
*Gari*_tra	3.20 ±0.01a	3.00 ±0.01a	3.10 ±0.01a	3.00 ±0.01a	3.20 ±0.01	3.10 ±0.01a	3.20 ±0.01a	3.30 ±0.01a	12.90 ±0.01a,b

Mean values ± standard deviation of replication analysis. Values followed by the same letter in the column are not significantly different at $p < 0.05$. *Gari*_1-3 equal to 37.5-36.5 sizes; *Gari*_4 (36.3); *Gari*_5 (35.9); *Gari*_6 (35.5); *Gari*_7 (35.1); *Gari*_25 is significantly lower than *Gari*_7; *Gari*_tra (control).

Table 4b

Hedonic test resuming overall sensation of different types of *gari* semolina.

Samples	Taste-water	Touch appearance				Mouth feeling		
	Appreciation	Colour	Fibre	Roundness	Adhesive	Swelling	Flavor	General
*Gari*_1-3	4.00 ±0.01a	2.90 ±0.01a	2.50 ±0.01a	1.70 ±0.01b	2.80 ±0.01a	2.00 ±0.01b	3.30 ±0.01a	19.30 ±0.01a,b
*Gari*_4	3.30 ±0.01a	3.10 ±0.01a	3.50 ±0.01a	2.70 ±0.01a	3.80 ±0.01a	2.70 ±0.01a	3.20 ±0.01a	22.30 ±0.01a,b
*Gari*_5	3.30 ±0.01a	3.20 ±0.01a	4.30 ±0.01a	2.20 ±0.01b	3.80 ±0.01a	2.50 ±0.01a	3.20 ±0.01a	22.50 ±0.01a,b
*Gari*_6	3.00 ±0.01a	3.30 ±0.01a	3.80 ±0.01a	2.80 ±0.01a	3.70 ±0.01a	2.00 ±0.01b	2.70 ±0.01a	21.30 ±0.01a,b
*Gari*_7	3.80± 0.01a	2.40 ±0.01b	3.80 ±0.01a	2.80 ±0.01a	4.30 ±0.01a	2.50 ±0.01a	3.00 ±0.01a	22.80 ±0.01a,b
*Gari*_25*	2.70 ±0.01a	3.20 ±0.01a	2.00 ±0.01b	3.70 ±0.01a	1.50 ±0.01b	3.20 ±0.01a	2.60 ±0.01a	18.80 ±0.01a,b
*Gari*_tra	3.50 ±0.01a	2.90 ±0.01a	4.50 ±0.01a	3.00 ±0.01a	4.30 ±0.01a	2.70 ±0.01a	3.00 ±0.01a	23.90 ±0.01a,b

Mean values ± standard deviation of replication analysis. Values with the same letter in the column are not significantly different at $p<0.05$. *Gari*_1-3 equal to 37.5-36.5 sizes; *Gari*_4 (36.3); *Gari*_5 (35.9); *Gari*_6 (35.5); *Gari*_7 (35.1); *Gari*_25 is significantly lower than *Gari*_7.

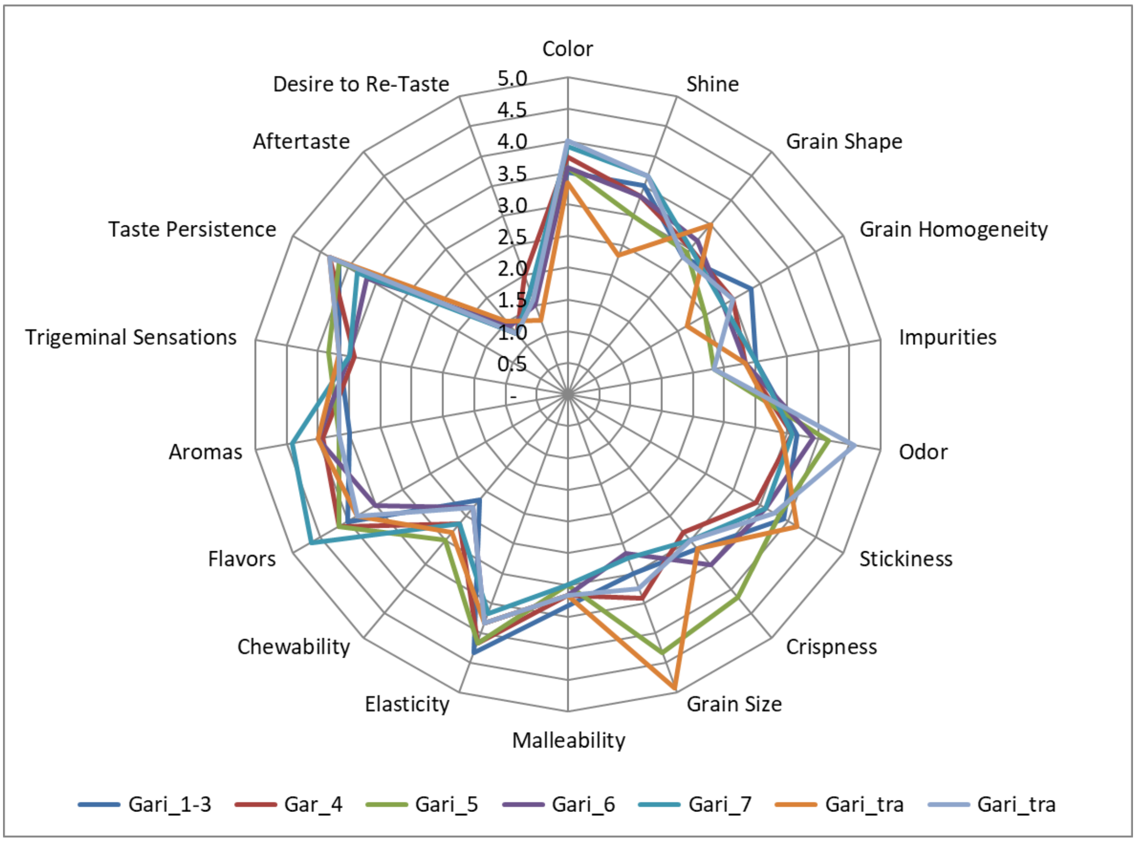

Fig. 5. Sensory profiles of *gari* semolinas.

A common overall rating was observed for the *gari* obtained from semolina production within the angle range of 35.5 to 37.5 degrees. According to the panel, there was no significant difference in the attributes of these different *gari.* All these evaluated *gari* were rated as: very acceptable and good sensory quality, less fibrous, good grain shape, very appreciable grain texture and shape, appealing taste, attractive aroma, good swelling and easy to eat. In fact, all the *gari* came from a single cassava variety (IAC). This could explain the similarity observed in attributes such as colour, impurities, friability, aroma, and shine. On the other hand, the optimal threshold of the inclination of the semolina was not exceeded. In other words, all the *gari* semolinas were obtained after an ideal level of inclination, with values ranging from 37.5° to 35.1°. This could also explain the similarity observed in attributes such as grain shape and size, which are the primary attributes. Furthermore, the semolinas of *gari* obtained at semouleur inclinations ranging from 25° to 32° were markedly different from the traditional ones. They were all judged to be poor quality, being generally unattra-ctive and coarse.

4 Conclusion

Semolinas of *gari* obtained at inclinations between 37.5° to 35.1° have organoleptic characteristics identical to those of traditional semolinas. The sensory characteristics of these *gari*, such as grain shape, grain size and "grain homogeneity", are very similar to those of the control semolinas, unlike the other semolinas. Therefore, at a pressing force of 2.58 kN, cassava dough semolina at an inclination angle of 37.5 to 35.1 degrees ideally produces semolinas of the same size as the control semolinas.

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