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Original Research Article

Evaluation of the Effect of Compost on the Organoleptic Quality (Taste and Consistency) of Okra (*Abelmoschus esculentus*) in an Agroecological System in the Sudano-Sahelian Zones of Mali: The Case of Bougouni and Bankass

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Abstract: In Mali, the widespread decline in soil fertility and the effects of climate change are major challenges for sustainable agriculture, especially for smallholder farms. The high cost of mineral fertilisers, their limited effects on the taste quality of crops, as well as their environmental and health impacts, underline the need for alternative options. This study aims to promote an agroecological approach through the use of organic composts to improve the production and organoleptic quality (taste and consistency) of okra (Abelmoschus esculentus), a strategic crop for food and nutrition security in Mali. The study was conducted for three years in two contrasting agroecological zones (Bankass and Bougouni), using two types of composts (pit and heap) applied at two doses (7.5 t/ha and 15 t/ha), compared to 2 controls, one of which was unapplied and another with mineral fertilization, following a randomized Fisher block design in three replicates. The results showed that the application of compost significantly improves the sensory properties of okra, including the taste of fresh okra sauces and the consistency of dried okra-based sauces. The combined treatment (T5), integrating the 2 types of compost at 15 tonnes/ha, obtained the best performance. Conversely, the witnesses recorded the lowest levels of appreciation. The use of compost thus appears to be a local, sustainable and accessible solution to improve soil fertility, yields and the nutritional quality of okra.

Keywords: Okra, Compost, Organoleptic Quality, Agroecology, Sensory Characteristics, Mali.

1. INTRODUCTION

Vegetables occupy a strategic place in Mali's agricultural production, with an annual production exceeding 3 million tons in 2019 and a wide diversity of varieties grown (Dembélé *et al*., 2022). The sector plays a key role in reducing poverty, promoting food and nutrition security, and improving rural household incomes. Vegetables are known for their multiple benefits on human health: they strengthen the immune system, contribute to the prevention of non-communicable diseases and effectively fight malnutrition. Their daily consumption, in sufficient quantities, is strongly recommended as part of a diversified and balanced diet (FAO, 2021). As such, the World Health Organization (WHO) recommends a minimum intake of 400 grams of fruits and vegetables per day, or five 80-gram servings (FAO, 2021).

Among the most valued vegetables in Mali is okra (Abelmoschus esculentus), whose nutritional value exceeds that of tomatoes according to several studies (Hamon & Charrier, 1997). The young fruits of okra are rich in carbohydrates, proteins, vitamins A and C, as well as minerals such as iron, phosphorus, potassium and magnesium (Hamon & Koechlin, 1991; Nzikou and *al*., 2006). They also contain mucilage with various functional properties: stabilization of dispersions, substitution of blood plasma, fluidification of the liquid and blood systems (Marius and *al*., 1997). In addition, the fiber,

vitamin B9 and antioxidants present in okra make it a valuable food for people in developing countries, whose diets often rely on micronutrient-poor cereal crops (Kota and *al*., 2022).

The quality of vegetable crops, especially in terms of taste, texture and nutritional value, can be significantly improved by organic fertilization. Several studies have shown that soil amendment with compost or organic manure positively influences the biochemical parameters of plants, such as the content of chlorophyll, proteins, glucose, amino acids and ascorbic acid (Larson and *al*., 2000; Pfiffner and *al*., 1993; Xu and *al*., 2000; Baliah and *al*., 2015). In addition, studies on other crops such as strawberries have shown that organic fertilization improves sensory attributes such as aroma, fragrance and texture (Hennion and *al.*, 1999).

In the Sudano-Sahelian areas of Mali, marked by high climate variability and increasing pressure on agricultural resources (FAO, 2021), improving the quality of food production is a major challenge for the resilience of food systems and the enhancement of local value chains (CILSS, 2016). Okra, widely consumed for its nutritional and organoleptic qualities (Ali and *al*., 2014), nevertheless suffers from a gradual deterioration in its taste and consistency, often linked to soil impoverishment and intensive cultivation practices (Traoré and *al*., 2019). Faced with this observation, agroecology, based on the regeneration of agricultural ecosystems and the use of natural resources, offers promising alternatives, in particular through the use of compost as an organic amendment (Altieri, 2002). Several studies have shown that compost improves soil structure, nutrient availability and water retention, which can directly influence the sensory characteristics of vegetable crops (Mäder and *al*., 2002; Coulibaly and *al*., 2020).

However, little research has so far rigorously documented the effect of compost on okra's organoleptic attributes in Mali's specific agro-climatic contexts. It is in this perspective that this study is based, the aim of which is to determine the effect of different compost-based fertilization options on the organoleptic quality of okra in the Bougouni and Bankass areas.

2. MATERIALS AND METHODS

2.1 Study Website

The experiments were carried out in the cities of Bougouni and Bankass (Figure **1**). These two sites were chosen because of their contrast in terms of agronomic, soil and climatic characteristics.

In Bankass, the trials were set up in the experimental plots of the Bankass Vocational Training Institute (IFP) with geographical coordinates 14°04'57.7" North and 3°30'17.2" West.

In Bougouni, a portion of a producer's plots in the city of Bougouni were used. The geographical coordinates of the site are 11°25'38.5" North and 7°30'20.3" West.

- **Bougouni:** The city of Bougouni is located in the south of Mali with geographical coordinates of 11.425° North and -7.449° West. The climate is pre-Guinean, with an average annual rainfall of 1199 mm (±165 mm) over the period 1994-2023. Maximum and minimum temperatures reach 34°C and 21°C respectively, with an annual average of 27°C (Coulibaly, 2024). The soils are of the hydromorphic tropical ferruginous type and the vegetation is characterized by a wooded and herbaceous savannah.
- **Bankass:** Bankass is located in the southeast of the country with geographical coordinates 14.055° North and -3.494° West. It has a Sahelian-like climate, with annual rainfall ranging from 500 mm (25th percentile) to 700 mm (75th percentile) for an average of 652 mm over the period from 2000 to 2020 (Mali-météo, 2024). The soils in this region are sandy-silty.

2.2 Factor Studied and Treatments Put in Competition

Only one factor was studied in this trial, namely the Compost-based fertilization taken at seven levels of variation. There are seven treatments applied, each corresponding to a specific level of variation in the factor studied. They are made up of 5 levels of compost, two types of which are taken at 2 doses, 1 at a single dose and 2 controls, namely the mineral fertilisation popularised for okra and 1 absolute control without application (Table 1).

2.3 Experimental Design

The experiment was carried out in two sites (Bankass and Bougouni) following the Fisher block experimental design randomized to three blocks (repeats). Each block was made up of 7 elementary plots. Each experimental unit, made of planks, was 4 m long and 1.5 m wide, i.e. an area of 6 m². A spacing or footpass of 40 cm separated the experimental units from each other. Each block had an area of 54.8 m², of which 13.7 m was long and 4 metres wide. The blocks were separated from each other by a 1 m alley. The total size of the overall plot dedicated to the trial was 205.5 m², of which 15 m was long and 13.7 m wide (Figure 2).

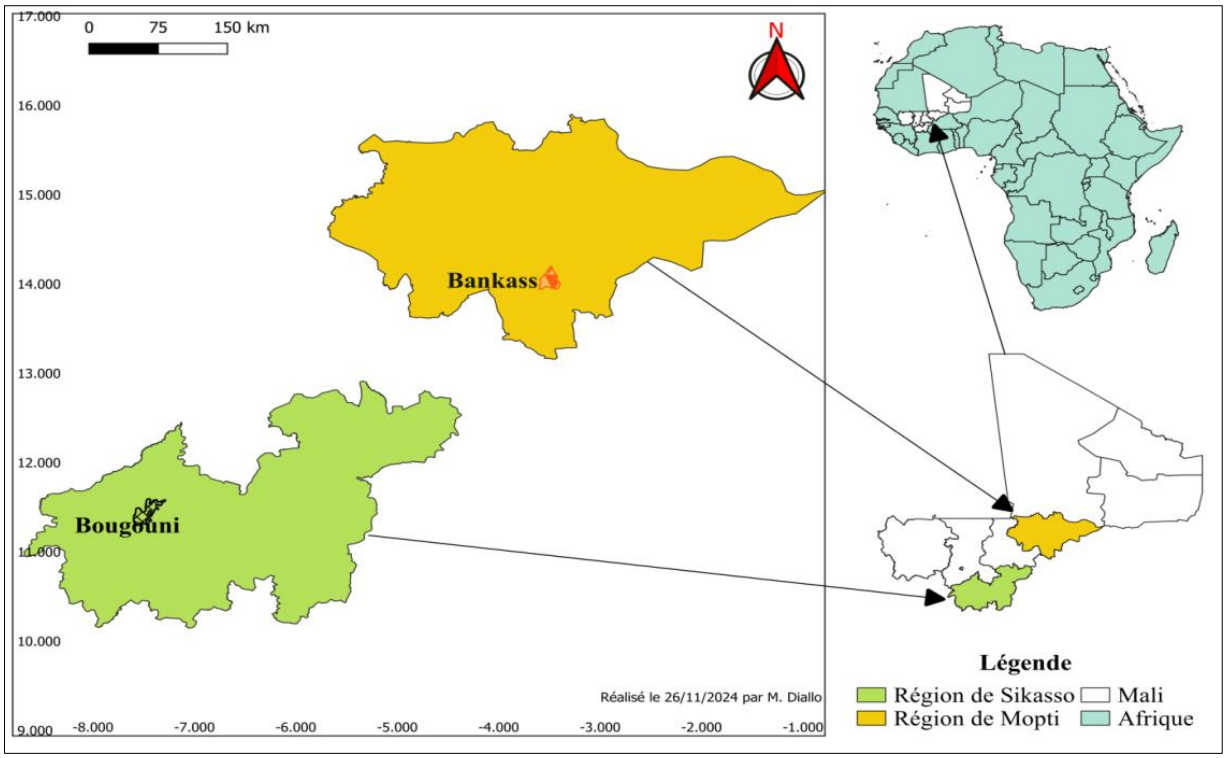

Figure 1: Map of the study's experimental sites (Oyahitt, 2023)

Table 1: Treatments in evaluation

Crop	Factor	Type of fertilizer	Rates (t/ha)	Trait No.
Okra	Fertilisation	Compost prepared in a pit	15	T1
		Compost prepared in a pile on the surface	15	T2
		Compost prepared in a pit	7,5	T3
		Compost prepared in a pile on the surface	7,5	T4
		Compost mix prepared in pits and piles on the surface	15	T5
		Mineral fertilizers (NPK and Urea)	0,5	T6
		No deposit	0	T7

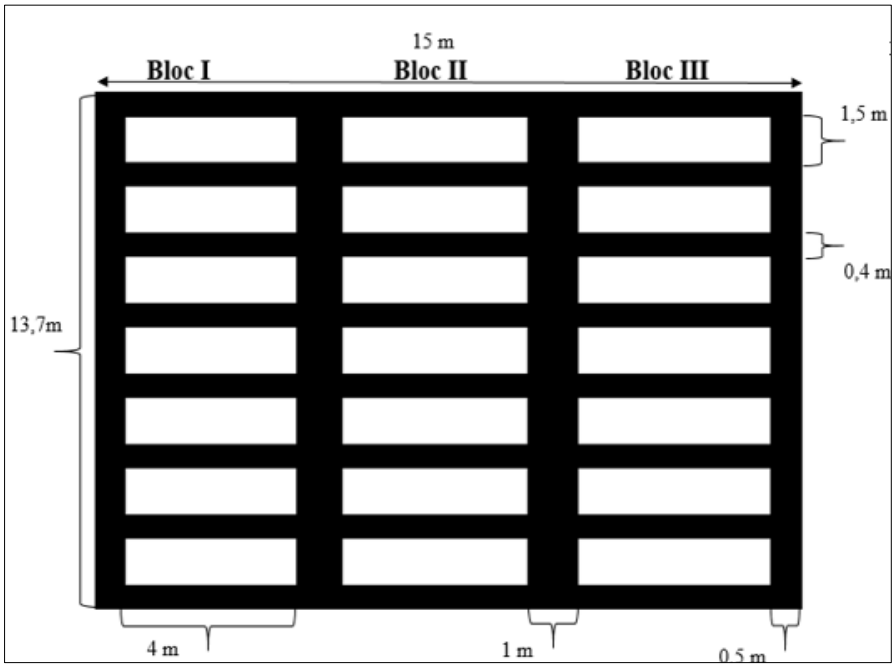

Figure 2: Ground plan of the experiment (Oyahitt, 2021)

2.4 Evaluation of fresh and dried okra sauces

Okra sauce is mainly prepared in two forms in Mali, namely the fresh fruit cut into small pieces giving the sauce commonly called gamboura (bambara) usually used with rice, the dried fruit and pounded to have the powder giving the gamougounan sauce (bambara) is generally used with the early. These two types (fresh and dried) have been evaluated through the sauces of which they are the basic ingredient.

The evaluation of the taste and organoleptic quality of the fresh okra fruits was made according to the treatments studied.

2.4.1 Evaluation of the Taste and Organoleptic Quality of Okra of Fresh Okra

- **Sample Conditioning:** 0.5 kg of the crop of each treatment was taken to constitute the sample to be distributed per unit to households and restaurants. The quantities taken were packaged separately.
- **Choice of Preparers and Preparation Process:** The conditioned samples were used for the preparation of okra sauce. About ten families were randomly selected with their consent, and a sample of each treatment was given to one family to be used in the preparation of 7 fresh okra sauces (Figure 3). Similarly, 3 mid-range restaurants were also chosen for the evaluation in the two areas. Each evaluator used the same usual processes used to prepare fresh okra sauce with the same ingredient dosages. The preparation faithful to the tasters' habits ensured that the results reflect the true characteristics of the products when consumed normally.

Figure 3: Preparation of okra at one of the families participating in the preparation session (OYAHITT, 2023)

2.4.2 Evaluation of the Taste Quality and Consistency of Dried Okra Fruit

- **Sample Drying and Packaging:** After harvest, the amount needed for evaluation was removed from each treatment. These fruits were dried for two weeks. This drying period was crucial to ensure that the fruits were properly prepared for a consistent assessment of their taste quality and consistency. Thus, the packaging was carried out with samples consisting of 200 g.
- **Choice of Preparers and Preparation Process:** The 200 g packaged samples were distributed to 10 other families and to the same 3 partner restaurants. Families were randomly selected from cities in the two study areas. The instruction was that each evaluator prepare the 7 dried okra samples by his usual method of preparation without changing either the process or the dosage of the ingredients. The same instruction was given for the 7 samples of fresh okra, thus allowing the products to be tested in real conditions.

2.5 Data Collection

Data were collected on several sensory criteria, including the flavour, aroma, texture, and consistency of fresh and dried fruit. Participants were able to express their opinion on each treatment produced according to its taste and sensory characteristics in a practical setting. The different sauces of the treatments were on two levels. The 1st level concerned families, each family after tasting gave a score to the sample tasted. The second level concerned the restaurants where the customers were our evaluators. Scores or scores ranged from 1 to 4 with 1 = unacceptable, 2 = acceptable, 3 = satisfactory and 4 = perfect. For the evaluation of fresh okra, the main criterion was flavor (taste). On the other hand, the main criterion for dried okra was consistency (viscosity).

Figure 4: Tasting phase of fresh okra (top left) and dried okra (top right) sauces and collection of assessments by collectors (Oyahitt, 2024)

2.6 Data Analysis

The data collected from the tasters' assessments was entered into an Excel file and then exported to the R software for analysis. A frequency distribution determining the overall level of appearance of the modalities was first performed, then the analysis through cross-sorting taking into account factors including treatment, treatments/years and treatments/sites were performed with the Chi-2 test at the 5% significance level.

3. RESULTS AND DISCUSSION

3.1 Taste Appreciation of Fresh Okra Sauces

3.1.1 General Taste Appreciation of Fresh Okra Sauces

The analysis of the overall taste appreciation of fresh okra sauces showed a significant difference (P = 0.0064) between the levels of appreciation. Overall, the reviewers were satisfied with 41% of the taste of the sauces evaluated. Thirty-three percent (33%) of reviewers found the taste of fresh okra's sauces to be perfect, while 21% found it to be acceptable. Only 5% of reviewers noted that the taste was unacceptable (Figure **5:**5).

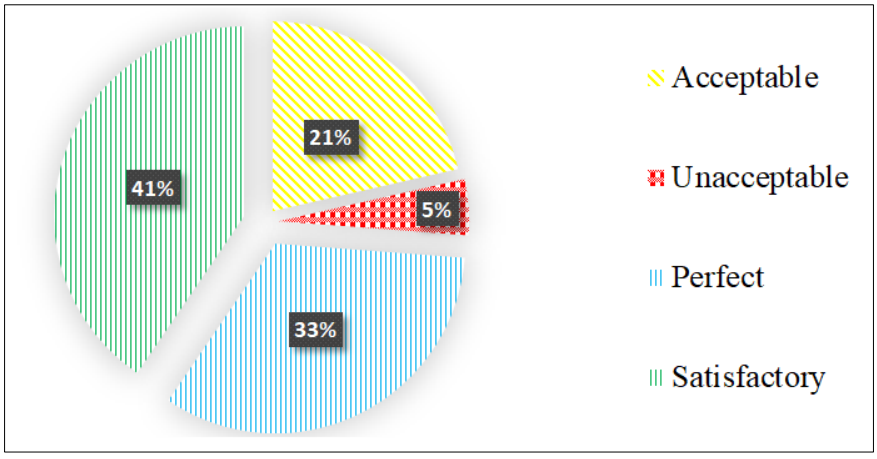

Figure 5: Level of methods for assessing the taste of fresh okra sauces

3.1.2 Appreciation of the Taste of Fresh Okra Sauces Depending on the Year

The result on the level of taste appreciation of fresh okra sauces according to the years did not show significant differences (P = 0.244) between the levels of appreciation according to the years. However, it should be noted that in 2021, the majority of reviewers found the taste of okra sauces to be satisfactory.

On the other hand, in 2022, the reviewers had opinions divided between the levels of appreciation, including 36% of perfect and acceptable opinions and 29% of satisfactory opinions. The highest levels of appreciation were observed in the final year of the study in 2023. Half of the participants in the evaluation noted that the taste of the fresh okra sauces was perfect. Other levels of appreciation of the taste of sauces were 36% for satisfactory, 7% for acceptable and also for unacceptable (Figure **6**6).

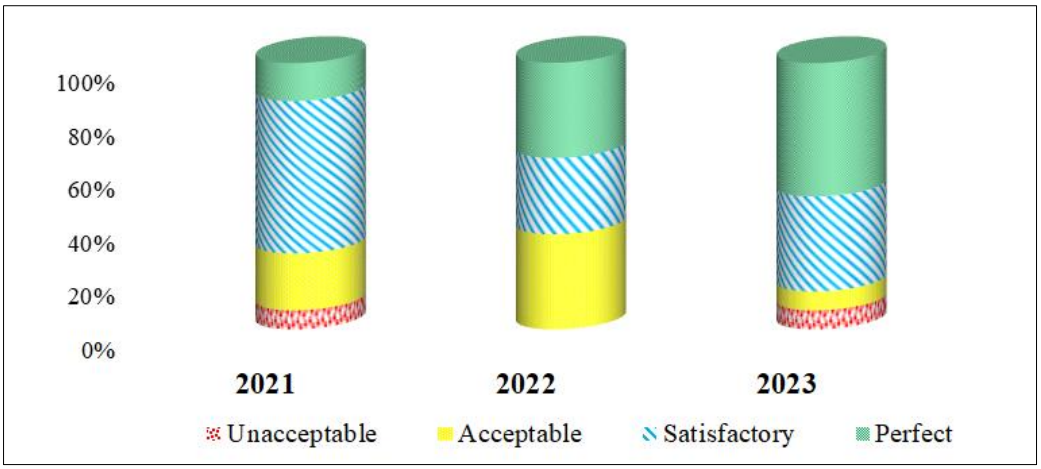

Figure 6: Level of taste appreciation methods according to the years

3.1.3 Appreciation of the Taste of Fresh Okra Sauces Depending on the Site

The result on the level of taste appreciation of fresh okra sauces showed no significant difference (P = 0.2405) between the two sites, relative to the level of appreciation**.** However, the best levels of appreciation were observed in Bougouni with 43% of perfect opinion against 31% in Bankass. Similarly, 43% of the evaluators found the taste of the sauces satisfactory in Bougouni compared to 33% in Bankass. They were 27% and 9% in Bankass found the taste of the sauces to be acceptable and unacceptable respectively, compared to 14% and 0% in Bougouni (Figure **7**7).

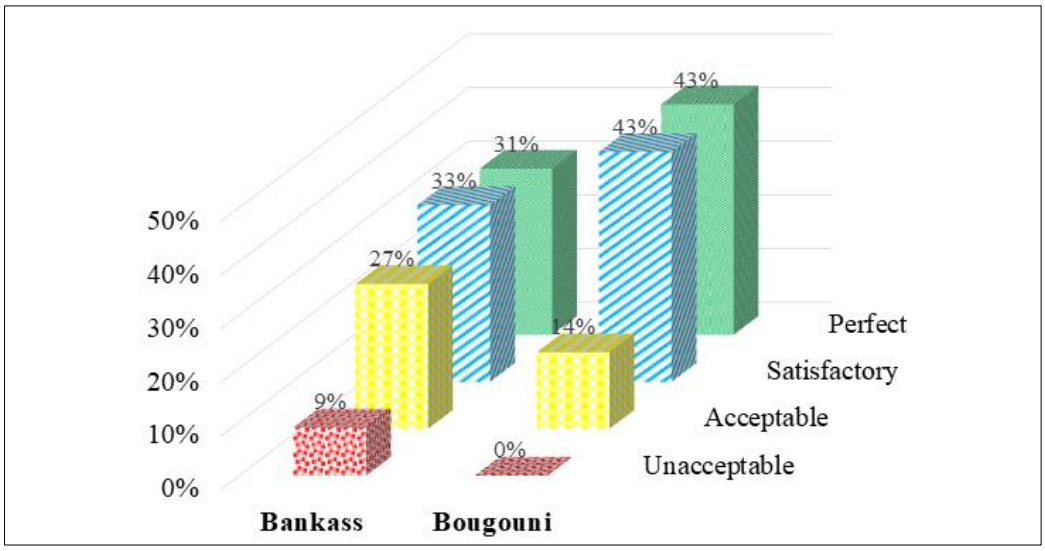

Figure 7: Level of taste assessment methods according to the sites

3.1.4 Appreciation of the Taste of Fresh Okra Sauces According to the Treatments

Analysis of the results on taste appreciation of fresh okra sauces showed a significant difference (P = 0.0024) between treatments regarding appreciation levels. The highest levels of (perfect) taste appreciation were achieved by Q2 with 26% and T1 and T3 with 21% each. The highest level of appreciation of the unacceptable taste modality was recorded by Q7 with 35% followed by Q6 with 28% (Table 2).

Table 2 : Levels of taste appreciation of fresh okra sauces according to the treatments

Treatment	Unacceptable (%)	Acceptable (%)	Satisfactory (%)	Perfect (%)
T1 (15 t compost in pit)	3	11	11	21
T2 (15 t compost in heaps)	15	0	8	26
T3 (7.5 t compost in pit)	10	6	12	21
T4 (7.5 t compost in pit)	2	0	19	14
T5 (15 t compost in pit + pile)	7	17	23	18
T6 (Mineral manure)	28	44	6	0
T7 (without deposit)	35	22	21	0
Chi-2 Test (P)	**0,002413**			

3.2 Appreciation of the Consistency of Dried Okra Sauces

3.2.1 General Assessment of the Consistency of Dried Okra Sauces

The result of the analysis of the overall appreciation of the consistency of dried okra sauces showed a significant difference (P = 0.0026) between the appreciation levels. Overall, almost half of the reviewers found the consistency of the sauces to be perfect (48%). In contrast, 24% and 21% of reviewers rated the consistency of the sauces as satisfactory and acceptable, respectively. Only 7% of reviewers rated the consistency as unacceptable (Figure 8).

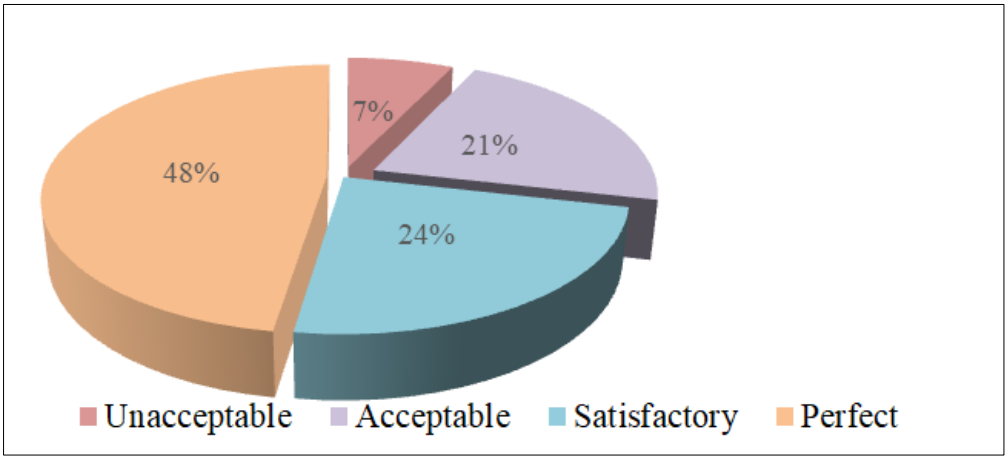

Figure 8: Level of methods for assessing the consistency of dried okra sauces

3.2.2 Assessment of the Consistency of Dried Okra Sauces According to the Year

The analysis of the level of appreciation of the consistency of dried okra sauces according to the years did not show significant differences (P = 0.721) between the levels of appreciation according to the years. In 2021, the majority (58%) of reviewers found the consistency of dried okra's sauces to be perfect. Similarly, in 2022, the majority (57%) of reviewers noted that the consistency of the dried okra's sauces was perfect. On the other hand, in 2023, the reviewers had opinions divided between the levels of appreciation, including 31% of perfect opinion, 36% of satisfactory opinion and 29% of acceptable opinion. Opinions noting that the consistency of sauces has been unacceptable have been very low over the 3 years with only 6%, 2% and 5% respectively in 2021, 2022 and 2023 (Figure 9).

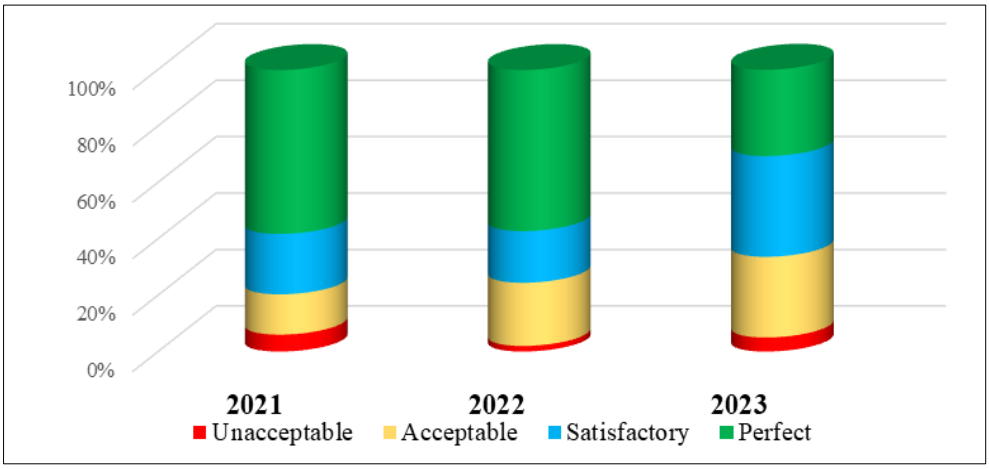

Figure 9: Level of appreciation of the consistency of dried okra sauces according to the year

3.2.3 Assessment of the Consistency of Dried Okra Sauces According to the Site

At the 5% significance level, there was no significant difference (P = 0.093) between the two sites in the levels of appreciation of the consistency of dried okra sauces**.** However, the rate of appreciation indicating that the consistency of the sauces was perfect was the highest in both sites with 57% in Bankass and 38% in Bougouni. At the last site, 33% indicated that the consistency was satisfactory compared to 14% in Bankass. Those who noted that the consistency was acceptable and unacceptable in Bankass were 18% and 10% respectively, compared to 29% and 0% in Bougouni (Figure 10).

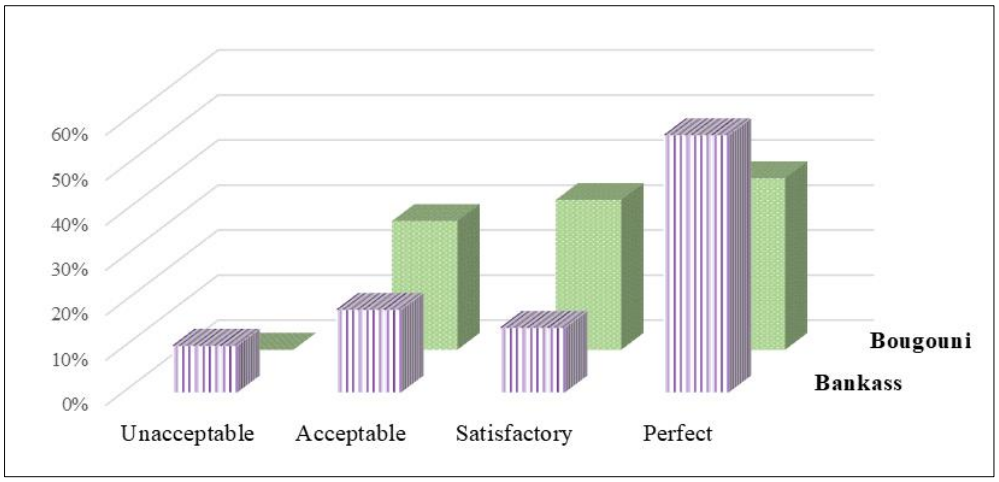

Figure 10: Level of appreciation of the consistency of dried okra sauces according to sites

3.2.4 Assessment of the Consistency of Dried Okra Sauces According to the Treatments

The analysis of the results on the assessment of the consistency of dried okra sauces showed a significant difference (P = 0.0024) between the treatments compared to the assessment methods. The modality expressing the best quality of appreciation (perfect) was higher in T1 and T2 with 25% each, followed by T3 and T5 with 20% each. Q4 recorded the highest rate of satisfactory modality with 40% followed by Q3 (20%). Levels of appreciation expressing poor qualities, in particular acceptable and unacceptable modalities, were the most observed in Q7 with 44% and 67% respectively.

Table 3 : Levels of appreciation of the consistency of dried okra sauces

Treatment	Unacceptable (%)	Acceptable (%)	Satisfactory (%)	Perfect (%)
T1 (15 t compost in pit)	0	0	10	25
T2 (15 t compost in heaps)	0	0	10	25
T3 (7.5 t compost in pit)	0	0	20	20
T4 (7.5 t compost in pit)	0	0	40	10
T5 (15 t compost in pit + pile)	0	11	10	20
T6 (Mineral manure)	33	44	10	0
T7 (without deposit)	67	44	0	0
Chi-2 Test (P)	**0,001026**			

3.3 Average Return over the 3 Years of the Study

In view of the results on the average yield over the 3 years of the experiment, it is clear that the doses of 15 tonnes/ha of the two types of compost induced the best yields in the two sites. In Bougouni, T1 was the best performer in terms of yield with 7601 kg/ha followed by T5 and T2 with 7165 kg/ha and 7146 kg/ha respectively. Similarly, in Bankass, the treatments with the highest yields were T5 (7553 kg/ha), T2 (7083 kg/ha) and T1 (6944 kg/ha) (Table 4).

Table 4 : Average yield of okra over the 3 years of the study at the two sites

Statistical parameters	Yield (kg/ha)	
	Bougouni	Bankass
T1 (15 t compost in pit)	7 601	6 944
T2 (15 t compost in heaps)	7 146	7 083
T3 (7.5 t compost in pit)	6 371	6 024
T4 (7.5 t compost in pit)	5 819	6 672
T5 (15 t compost in pit + pile)	7 165	7 553
T6 (Mineral manure)	6 970	6 265
T7 (without deposit)	4 548	4 223
Average	6 517	6 395
Standard deviation	2 092	2 344
Coefficient of variation	0,37	0,32
Minimum	3 701,67	3 442
Maximum	13 964,33	12 053
ANOVA (P)	**0,041**	**0,027**

DISCUSSION

The frequencies of the general appreciation of the taste of fresh okra sauces and the consistency of dried okra varied significantly between tasters. This would mean that consumers have different sensitivities from each other in terms of taste. This difference between consumers is explained by the variable nature of humans.

Neither the years nor the sites have influenced the taste appreciation levels and consistency (viscosity) of fresh and dried okra sauces. This could indicate that whatever the year or the site, the taste quality of fresh okra sauces and the consistency of dried okra sauces vary very little. According to Falade, and Omojola, (2008), the organoleptic quality of okra samples from the same source and which are processed/stored according to the same protocol remains the same from year to year.

The methods of appreciating the taste of fresh okra sauce varied significantly depending on the treatment, indicating that the doses and types influence the taste quality of fresh okra sauces. Doses of 15 t/ha of compost in pits or piles were best appreciated for the taste of fresh okra sauces. Similar results to ours have been obtained by several authors Baliah et *al*., (2015) have shown that the sensory quality of okra can be influenced by cultural practices and organic fertilization. The results of Adewole and Illesanmi (2011), noted that fruits grown with compost were judged to be of better nutritional quality. The compost improved the protein, mineral and fiber content in the okra fruits, compared to controls. In the same vein, the recent work of Acharya et *al*., (2024), highlighted that the different types of vermicompost had variable effects, but overall, they increased the yield and size of the fruits that were more tender and more sensorially appreciated.

The viscosity of sauces made from dried okra is an aspect that is highly appreciated by consumers in Mali, hence its use as a binder in sauces (Hamon & Charrier, 1997). The assessment of the consistency (viscosity) of the dried okra sauces showed a significant difference between the treatments compared to the assessment methods. Doses of 15 t/ha of compost in pits and piles induced the best quality of consistency in the dried okra sauces. The influence of compost on the consistency and taste of okra sauces is confirmed by Gemede and Ratta (2015) who noted that compost induces a high content of minerals (Ca, K, Mg) and mucilage in okra, which is decisive for its texture. Similarly, Baliah *et al*., (2015) demonstrated a significant increase in biochemical parameters (total chlorophyll, protein, glucose, ascorbic acid, NR activity) in plants amended with organic fertilizers, compared to unfertilized controls.

The results show that organic composts, whether from pits or piles, induce a significant improvement in the organoleptic characteristics of fresh fruits, compared to controls. This improvement is explained by the diversified supply of nutrients, promoting the development of tastier and better structured fruits. The synergistic effect observed with the combined treatment (T5) suggests that the combination of different compost sources could optimize nutrient inputs and enrich soil microbial diversity, with positive effects on fruit quality. This trend is confirmed by the work of Traoré *et al*., (2019), who show that cultural practices incorporating organic amendments improve the taste and texture of okra in Mali.

In addition, it is clear that the doses of 15 tonnes/ha of the two types of compost induced the best yields in both sites. To this end, Amissah (2015) noted that compost inputs not only increase the yield of okra by 25 to 40%, but also contribute to improving the firmness and color of the fruits with a reduction in acidity and an increase in dry matter content.

4. CONCLUSION

The results of this study confirm that the organoleptic quality of okra, both fresh and dried, is strongly influenced by fertilization methods, in particular organic compost-based treatments. Sensory analysis revealed an overall positive assessment of the sauces, with significant variations between treatment types, but not between years or sites, highlighting the robustness of the effects related to cultural practices.

Organic composts have been shown to improve okra fruit yield, taste and consistency of sauces, promoting balanced plant nutrition and better fruit structuring. Conversely, mineral treatments and the absence of amendments have shown significant limitations in terms of sensory quality, reinforcing the agronomic and culinary interest of compost-based fertilisations.

These results are part of a dynamic of promoting agroecological practices, in line with traditional Malian uses and international references on vegetable quality. They open up promising prospects for improving okra production systems, integrating consumer preferences and nutritional requirements, while strengthening the sustainability of agroecosystems.

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