

Effects of Soybean and Okra Seed Incorporation on the Functional, Nutritional and Sensory Properties of Maize Pap Powder

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Abstract—This study evaluated the effects of incorporating soybean and okra seed powders into maize pap on its functional, proximate, mineral and sensory properties. Six formulations reported in the study were evaluated: MS6 (60% maize, 30% soybean, 10% okra), MS8 (80% maize, 15% soybean, 5% okra), MS10 (100% maize), MM4 (60% maize, 30% soybean, 10% okra), MM6 (80% maize, 15% soybean, 5% okra) and MM8 (60% maize, 25% soybean, 15% okra). Functional, proximate, mineral and sensory properties were determined using the analytical procedures stated in the original study, while data were analysed by ANOVA and Duncan's Multiple Range Test at $p < 0.05$. Bulk density ranged from 0.70 to 0.79 g/cm³, water absorption capacity from 180.40 to 225.15%, oil absorption capacity from 110.26 to 135.25%, and swelling index from 105.45 to 118.90%. Moisture, ash, crude fibre, fat, protein and carbohydrate contents ranged from 8.37–10.75%, 0.58–0.92%, 0.54–0.72%, 2.21–8.38%, 6.75–11.54% and 69.48–78.73%, respectively. Mineral contents varied significantly among samples, with soybean and okra inclusion generally increasing magnesium, calcium, iron and zinc relative to the 100% maize control. Sensory scores on a 9-point hedonic scale showed that the control had the highest overall acceptability (8.30), although the fortified samples remained acceptable. The findings indicate that soybean and okra seed incorporation can improve the nutritional and functional quality of maize pap while retaining acceptable sensory characteristics.

Index Terms—Maize pap; soybean; okra seed; complementary food; functional properties; sensory evaluation.

I. INTRODUCTION

Pap, commonly known as ogi or akamu in Nigeria, is a fermented cereal-based food traditionally prepared

from maize, sorghum or millet. It is widely consumed as a breakfast food and as a complementary food because of its smooth texture, sour taste and ease of preparation. Traditional processing of maize into pap involves steeping, wet milling, sieving, fermentation, decanting and drying, operations that influence the nutritional and functional characteristics of the final product (Abdulrahman & Kolawole, 2006; Akinrele, 2021).

Although maize pap is inexpensive and culturally accepted, maize-based foods are relatively limited in protein and some micronutrients. Fortification with plant protein sources has therefore been investigated as a means of improving the nutritional quality of ogi and related complementary foods. Soybean is particularly useful because of its relatively high protein content, while okra seed provides protein, fat and other nutrients and can contribute functional properties to food systems (Ademiluyi & Oboh, 2018; Ilesanmi & Adeyeye, 2020; Ijarotimi & Keshinro, 2018).

Previous studies have reported that incorporation of legumes and other plant materials into maize pap can improve proximate composition and selected functional properties, although the level of substitution may also affect colour, flavour, mouthfeel and overall acceptability (Adegunwa et al., 2017; Adeola & Aworh, 2018; Ajani & Akinyele, 2021). Fermentation and subsequent drying are also important because they influence the physical and nutritional quality of the product and its storage stability (Adegbehingbe, 2020; Adelekan & Oyewole, 2019).

There is therefore a need to evaluate combinations of maize, soybean and okra seed that provide improved nutrient density without causing unacceptable sensory

changes. This study investigated the effects of the reported soybean and okra seed incorporation treatments on the functional, proximate, mineral and sensory properties of powdered maize pap.

II. MATERIALS AND METHODS

2.1 Materials

Dried yellow maize (4.5 kg), dried brown soybean (2.5 kg) and fresh okra fruits/pods (4 kg) were purchased from Anyigba Central Market, Anyigba, Kogi State, Nigeria. Reagents used for the analyses were obtained from the Analytical Laboratory of the Department of Biochemistry, Prince Abubakar Audu University, and were of analytical grade.

2.2 Preparation of raw materials

Okra seeds were obtained by washing the fresh pods, breaking them and manually removing the seeds. The seeds were blanched in boiling water for 5 min, drained and dried at 55 °C for 8 h in a hot-air oven (Model SX3-4.5-15, China).

Soybean seeds were sorted to remove wrinkled seeds, stones, plant materials and dust. The seeds were washed, soaked in excess clean water for 8 h and dehulled by rubbing between the palms. The dehulled soybean cotyledons were cleaned and used for the formulations.

Maize grains were cleaned and sorted to remove unwanted materials, stones and dust. The grains were steeped in excess water at room temperature for 24 h, followed by decanting and rinsing before blending with the prepared soybean and okra seed materials.

2.3 Production of pap powder

For each formulation, the required quantities of fermented maize, dehulled soybean and blanched okra seed were weighed and thoroughly blended. The control consisted of 100% fermented maize. Each mixture was wet-milled and wet-sieved. The resulting suspension was allowed to settle and ferment for 24–48 h. The supernatant was decanted and the retained pap material was spread thinly on trays. The samples were dried at 55 °C for 72 h, milled and sieved to obtain the powdered pap. The processing sequences are shown in Figures 1 and 2.

2.4 Experimental formulations

The formulations reported in the source manuscript are presented in Table 1. The paired MS and MM sample codes were retained exactly as reported because the original manuscript assigns the same ingredient ratios to MS6/MM4 and MS8/MM6.

2.5 Analytical procedures

Functional properties were determined using the method attributed to Onwuka (2018) in the source manuscript. Proximate composition and mineral composition were determined using AOAC (2012) procedures as reported in the source. Sensory quality was evaluated using the method attributed to Nwankwo et al. (2015), with a 9-point hedonic scale.

2.6 Statistical analysis

Data were subjected to analysis of variance (ANOVA) using SPSS version 21.0. Duncan's Multiple Range Test (DMRT) was used to separate treatment means at the 5% probability level. Differences were considered significant at $p < 0.05$.

III. RESULTS AND DISCUSSION

3.1 Functional properties

The functional properties of the powdered pap are presented in Table 2. Bulk density ranged from 0.70 g/cm³ in MM8 to 0.79 g/cm³ in MS10. The control, MS10, had the highest bulk density, whereas MM8 had the lowest. The lower bulk density of the composite samples may be associated with the incorporation of soybean and okra seed components that alter particle structure and packing. Similar improvements in functional characteristics have been reported for maize pap and ogi fortified with plant protein sources (Olaoye et al., 2019; Osungbaro et al., 2021).

Water absorption capacity ranged from 180.40% in MS10 to 225.15% in MM8, while oil absorption capacity increased from 110.26% in MS10 to 135.25% in MM8. The higher absorption values in the composite samples are consistent with the contribution of proteins and other water- and oil-binding constituents from soybean and okra seed. Ajani and Akinyele (2021) similarly reported that okra seed flour can modify the functional behaviour of maize-based pap.

Swelling index increased from 105.45% in MS10 to 118.90% in MM8. In contrast, solubility was highest in MS10 (18.25%) and lowest in MM8 (15.20%). These differences indicate that incorporation of soybean and okra seed altered the balance between starch and non-starch components. The observed changes are relevant to pap preparation because water absorption, swelling and solubility influence reconstitution, thickness and mouthfeel (Oyeleke & Eleyinmi, 2019; Osungbaro et al., 2021).

Gelatinization temperature ranged from 70.20 °C in MS10 to 73.55 °C in MM8. The slightly higher values in the composite samples may reflect interactions between starch and the protein- and fibre-containing ingredients. Overall, the functional results suggest that soybean and okra seed incorporation modified the hydration and thermal behaviour of the pap powders.

3.2 Proximate composition

Table 3 shows significant variation in the proximate composition of the samples. Moisture content ranged from 8.37% in MM8 to 10.75% in MS10. The lower moisture content of the composite samples, particularly MM8, is favourable for a dry pap powder because reduced moisture can limit deterioration during storage. Similar effects of soybean enrichment and processing on the moisture and storage characteristics of maize-based foods have been reported (Adelekan & Oyewole, 2019; Adegunwa et al., 2017).

Ash content increased from 0.58% in MS10 to 0.92% in MM6. This pattern indicates an increased contribution of mineral-containing components from soybean and okra seed. The trend agrees with reports that incorporation of plant protein sources into ogi can improve the mineral-associated ash fraction (Akingbala et al., 2019; Amankwah et al., 2020).

Crude fibre ranged from 0.54% in MS8 to 0.72% in MM8. The highest value occurred in the formulation containing 15% okra seed, supporting the contribution of seed materials to the fibre fraction. Fat content increased markedly with soybean and okra incorporation, ranging from 2.21% in MS10 to 8.38% in MS6. Soybean is a relatively lipid-rich legume, and its inclusion therefore increased the fat fraction of the pap.

Protein content ranged from 6.75% in MS10 to 11.54% in MM6. The control had the lowest value, whereas the soybean-containing samples had

substantially higher protein concentrations. This result demonstrates the contribution of soybean to the protein density of maize pap and agrees with previous studies on soybean-fortified complementary foods (Ademiluyi & Oboh, 2018; Ijarotimi & Keshinro, 2018). Carbohydrate content showed the reverse trend, ranging from 69.48% in MS6 to 78.73% in MS10. The lower carbohydrate values in the composite samples reflect replacement of part of the maize fraction with soybean and okra seed.

3.3 Mineral composition

The mineral composition is presented in Table 4. Magnesium ranged from 55.05 mg/100 g in MS10 to 133.05 mg/100 g in MM4, while calcium ranged from 138.50 to 334.44 mg/100 g. Phosphorus varied from 132.51 to 512.24 mg/100 g. These differences show that formulation influenced the mineral density of the pap. The generally higher mineral values of the composite samples are consistent with reports of improved nutrient composition in maize-based complementary foods fortified with soybean and okra seed materials (Amankwah et al., 2020; Olusanya et al., 2022).

Iron showed a wide range, from 37.01 mg/100 g in MM6 to 502.28 mg/100 g in MS6, while zinc ranged from 5.83 mg/100 g in MS10 to 9.46 mg/100 g in MM8. The variation in iron and zinc suggests that both ingredient proportion and processing may have influenced the measured mineral concentrations. Processing is known to affect the nutritional composition of cereal-legume blends (Akande & Fabiyi, 2020), and the mineral contribution of okra seed has also been reported (Ilesanmi & Adeyeye, 2020).

Overall, MS10, the 100% maize control, generally had lower mineral concentrations than the fortified formulations. MM8 combined relatively high calcium, magnesium and zinc values, whereas MS6 had the highest measured iron value. These results support the potential of soybean and okra seed incorporation for increasing the mineral density of maize pap, although mineral bioavailability was not measured in the present study.

3.4 Sensory properties

Sensory evaluation results are shown in Table 5. MS10 recorded the highest appearance score (8.60), flavour score (8.65), mouthfeel score (8.20), taste score (8.50),

consistency score (8.60) and overall acceptability score (8.30). The high scores for the control are consistent with the familiarity of conventional maize pap and indicate that fortification can introduce sensory changes that reduce preference. Nevertheless, the composite samples remained within the acceptable region of the 9-point hedonic scale.

Among the fortified samples, MM4 and MM6 showed comparatively good overall acceptability scores of 7.95 and 7.62, respectively. The lower scores observed for some samples containing greater proportions of okra seed may be associated with changes in flavour, mouthfeel and consistency. Similar sensory effects have been reported when soybean and okra seed materials are incorporated into cereal-based complementary foods (Chikwendu et al., 2020; Nnamani et al., 2021; Olapade et al., 2018).

The sensory results therefore suggest that nutritional enhancement can be achieved without complete loss of consumer acceptance. In practical terms, MM4 and MM6 appear to provide a better compromise between nutritional enrichment and sensory preference, whereas MM8 provides strong mineral enrichment but a lower overall acceptability score than the control.

IV. CONCLUSION

The study demonstrated that incorporation of soybean and okra seed powders into maize pap modified the functional, proximate, mineral and sensory properties of the resulting pap powder. Compared with the 100% maize control, the composite formulations generally showed lower bulk density and moisture and higher water and oil absorption capacities, swelling index, ash, fat and protein. Mineral concentrations also varied

substantially with formulation, with several fortified samples showing higher magnesium, calcium, iron and zinc contents than the control.

Although the 100% maize control recorded the highest sensory scores, the fortified samples remained acceptable to the panelists. MM4 and MM6 provided comparatively good sensory acceptance while offering improved nutrient composition. The findings support the use of soybean and okra seed as locally available ingredients for nutritional enhancement of maize pap. Further work should examine shelf-life, antinutritional factors, amino-acid quality and mineral bioavailability before making specific dietary claims for vulnerable populations.

V. DECLARATIONS

5.1 Conflict of interest

The source manuscript does not state a conflict-of-interest declaration; this should be confirmed by the authors before submission.

5.2 Ethical approval

The source manuscript does not report an ethics approval number or committee. Because sensory evaluation involves human participants, the authors should insert the applicable ethical approval/consent statement before submission.

5.3 Generative AI disclosure

Generative AI was used only to assist with language editing, organization and manuscript formatting. The authors retain responsibility for the accuracy of the scientific content, data, interpretation and final submitted manuscript.

Table 1. Formulation of powdered pap samples

Sample code	Maize flour (%)	Soybean flour (%)	Okra seed (%)
MS6	60	30	10
MS8	80	15	5
MS10	100	—	—
MM4	60	30	10
MM6	80	15	5
MM8	60	25	15

Note: MS6 = 60% maize + 30% soybean + 10% okra seed; MS8 = 80% maize + 15% soybean + 5% okra seed; MS10 = 100% maize; MM4 = 60% maize + 30% soybean + 10% okra seed; MM6 = 80% maize + 15% soybean + 5% okra seed; MM8 = 60% maize + 25% soybean + 15% okra seed.

Table 2. Functional properties of powdered pap produced from maize, soybean and okra seed blends

Sample	Bulk density (g/cm ³)	Water absorption capacity (%)	Oil absorption capacity (%)	Swelling index (%)	Solubility (%)	Gelatinization Temp. (°C)
MS6	0.72 ^c ± 0.01	210.35 ^c ± 1.24	128.45 ^c ± 0.86	115.20 ^c ± 1.10	16.50 ^{cd} ± 0.15	72.80 ^b ± 0.20
MS8	0.75 ^b ± 0.02	195.22 ^c ± 1.10	120.33 ^c ± 0.78	110.65 ^d ± 0.85	17.12 ^b ± 0.10	71.50 ^c ± 0.18
MS10	0.79 ^a ± 0.01	180.40 ^f ± 1.32	110.26 ^f ± 0.91	105.45 ^e ± 0.75	18.25 ^a ± 0.12	70.20 ^d ± 0.25
MM4	0.71 ^c ± 0.02	215.48 ^b ± 1.15	130.58 ^b ± 0.80	116.75 ^b ± 0.60	15.80 ^d ± 0.14	73.10 ^{ab} ± 0.15
MM6	0.74 ^b ± 0.01	200.32 ^d ± 1.20	122.12 ^d ± 0.95	111.20 ^d ± 0.50	16.95 ^c ± 0.13	71.65 ^c ± 0.19
MM8	0.70 ^d ± 0.01	225.15 ^a ± 1.18	135.25 ^a ± 0.85	118.90 ^a ± 0.55	15.20 ^e ± 0.11	73.55 ^a ± 0.22

Values are means ± SD of duplicate determinations. Values in the same column with different superscripts are significantly different ($p < 0.05$).

Table 3. Proximate composition of powdered pap produced from maize, soybean and okra seed blends

Sample	Moisture (%)	Ash (%)	Crude fibre (%)	Fat (%)	Crude protein (%)	Carbohydrate (%)
MS6	10.00 ^c ± 0.00	0.72 ^d ± 0.03	0.56 ^c ± 0.00	8.38 ^a ± 0.02	10.85 ^b ± 0.05	69.48 ^f ± 0.12
MS8	10.18 ^b ± 0.28	0.67 ^c ± 0.04	0.54 ^c ± 0.07	5.54 ^c ± 0.07	8.58 ^c ± 0.03	74.52 ^c ± 0.00
MS10	10.75 ^a ± 0.07	0.58 ^f ± 0.02	0.56 ^c ± 0.01	2.21 ^f ± 0.02	6.75 ^f ± 0.03	78.73 ^a ± 0.36
MM4	9.87 ^d ± 0.04	0.85 ^c ± 0.04	0.64 ^{ab} ± 0.01	7.30 ^c ± 0.04	10.14 ^c ± 0.02	71.96 ^d ± 0.16
MM6	8.85 ^c ± 0.07	0.92 ^a ± 0.03	0.69 ^{ab} ± 0.01	8.08 ^b ± 0.11	11.54 ^a ± 0.06	70.30 ^c ± 0.22
MM8	8.37 ^f ± 0.09	0.87 ^b ± 0.03	0.72 ^a ± 0.02	6.28 ^d ± 0.14	8.88 ^d ± 0.07	75.36 ^b ± 0.04

Values are means ± SD of duplicate determinations. Values in the same column with different superscripts are significantly different ($p < 0.05$).

Table 4. Mineral composition of powdered pap produced from maize, soybean and okra seed blends

Sample	Magnesium (mg/100 g)	Calcium (mg/100 g)	Phosphorus (mg/100 g)	Iron (mg/100 g)	Zinc (mg/100 g)
MS6	124.35 ^c ± 0.50	314.70 ^{bc} ± 1.90	158.40 ^c ± 2.51	502.28 ^a ± 1.03	9.24 ^b ± 1.20
MS8	124.35 ^c ± 0.50	314.70 ^{bc} ± 1.90	512.24 ^a ± 1.76	46.22 ^d ± 0.43	9.14 ^b ± 0.18
MS10	55.05 ^d ± 0.65	138.50 ^d ± 2.10	132.51 ^c ± 1.79	346.02 ^c ± 1.44	5.83 ^c ± 1.03
MM4	133.05 ^a ± 0.10	332.06 ^b ± 0.63	169.00 ^c ± 1.00	46.28 ^d ± 0.86	6.76 ^{bc} ± 1.81
MM6	126.50 ^c ± 0.05	142.06 ^c ± 0.63	143.16 ^d ± 1.06	37.01 ^e ± 1.56	7.13 ^{bc} ± 0.81
MM8	129.94 ^b ± 0.76	334.44 ^a ± 1.00	273.30 ^b ± 1.15	408.28 ^b ± 2.34	9.46 ^a ± 1.56

Values are means ± SD of duplicate determinations. Values in the same column with different superscripts are significantly different ($p < 0.05$).

Table 5. Sensory attributes of powdered pap produced from maize, soybean and okra seed blends

Sample	Appearance	Flavour	Mouth feel	Taste	Consistency	Overall acceptability
MS6	7.10 ^c ± 1.11	6.70 ^d ± 1.12	6.76 ^{bc} ± 0.96	6.85 ^{bc} ± 1.18	6.85 ^{bc} ± 0.98	7.29 ^{bc} ± 0.96
MS8	6.90 ^d ± 1.02	6.60 ^d ± 1.50	6.68 ^{bc} ± 1.05	6.90 ^{bc} ± 1.05	6.85 ^{bc} ± 1.20	7.20 ^c ± 1.00
MS10	8.60 ^a ± 0.58	8.65 ^a ± 0.97	8.20 ^a ± 0.94	8.50 ^a ± 1.05	8.60 ^a ± 1.50	8.30 ^a ± 0.73
MM4	7.75 ^b ± 0.95	7.45 ^b ± 1.81	7.35 ^{ab} ± 0.96	7.85 ^{ab} ± 1.14	7.85 ^{ab} ± 1.06	7.95 ^{ab} ± 0.96

MM6	7.50 ^{bc} ± 0.83	7.40 ^{bc} ± 1.35	7.01 ^{bc} ± 1.16	8.00 ^{ab} ± 1.05	7.25 ^{ab} ± 1.10	7.62 ^{ab} ± 0.92
MM8	7.65 ^{bc} ± 1.08	7.35 ^{bc} ± 0.81	7.00 ^{bc} ± 1.07	6.75 ^{bc} ± 0.96	7.10 ^{bc} ± 0.78	7.65 ^{ab} ± 0.98

Values are means ± SD. Sensory evaluation used a 9-point hedonic scale. Values in the same column with different superscripts are significantly different ($p < 0.05$).

Figure 1. Processing flow diagram for maize pap powder

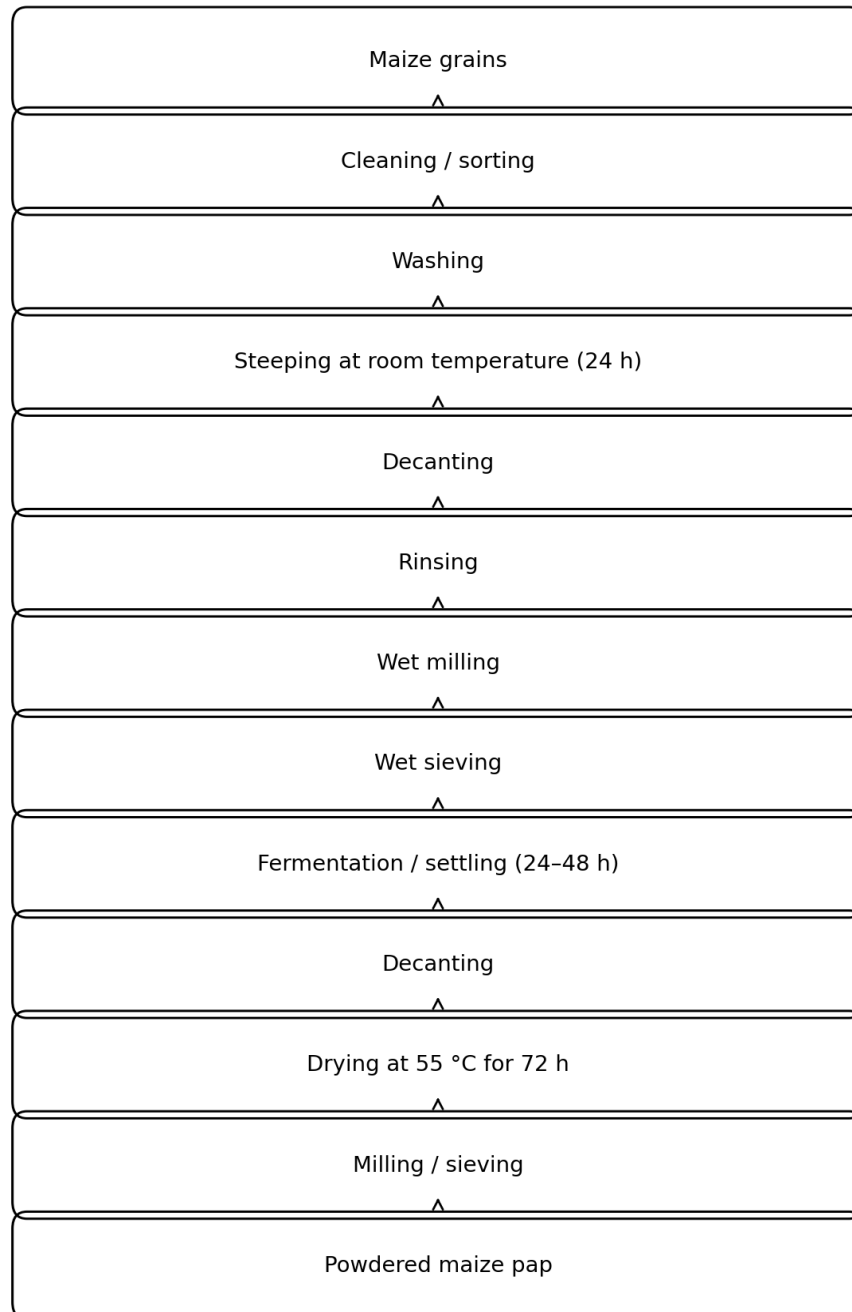


Figure 1. Processing flow diagram for maize pap powder

Figure 2. Processing flow diagram for soybean-okra seed fortified maize pap powder

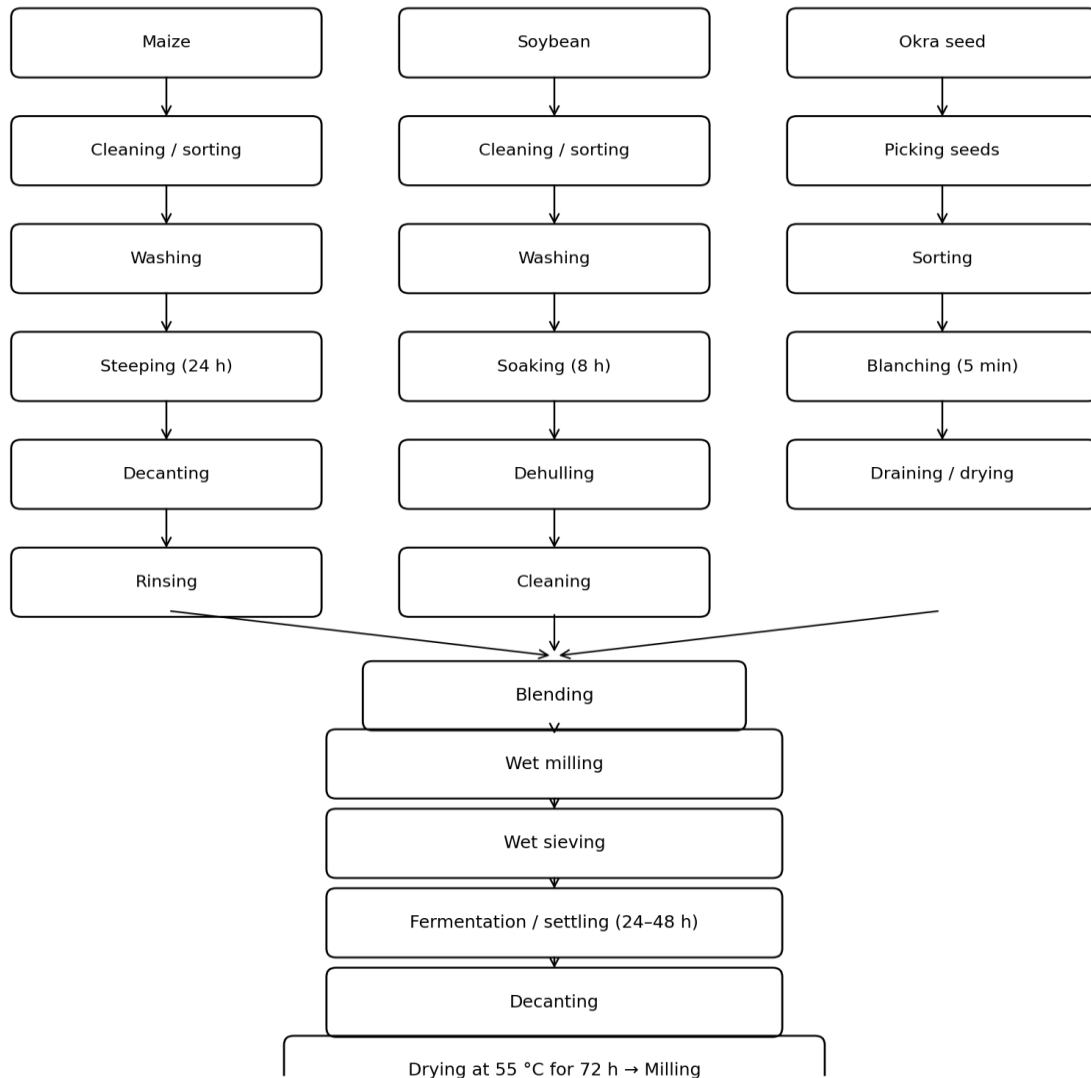


Figure 2. Processing flow diagram for soybean–okra seed fortified maize pap powder

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