Development and Shelf-Life Evaluation of Mayonnaise Formulated with Gossypol-Free Cottonseed Oil-Soybean Oil Blends: A Functional and Economic Assessment

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Abstract

Reformulating mayonnaise with nutritionally enhanced oils is a growing trend driven by consumer health awareness and demand for stable emulsified products. This study investigates mayonnaise formulations using gossypol-free cottonseed oil (GF-CSO) blended with soybean oil at 0%, 10%, 20%, and 30% GF-CSO levels. The physicochemical, rheological, sensory, and oxidative stability of the products were evaluated over 30 days of accelerated storage at 45°C. The 20% GF-CSO blend yielded superior sensory acceptance (overall score 8.6), enhanced emulsion stability, and reduced lipid oxidation markers compared to controls. Economic analysis demonstrated cost-effectiveness with a production cost of ₹153/kg. Findings highlight the feasibility of GF-CSO incorporation for developing shelf-stable, health-aligned mayonnaise, contributing to value-added utilization of cottonseed byproducts.

Keywords: Mayonnaise, gossypol-free cottonseed oil, emulsions, oxidative stability, sensory evaluation, cost analysis

1. Introduction

Mayonnaise is a complex oil-in-water emulsion stabilized primarily by egg yolk lecithin, requiring oils with optimal physicochemical properties for emulsion stability and oxidation resistance [Depree & Savage, 2001]. Conventional formulations utilizing soybean oil are prone to lipid oxidation due to high linolenic acid content, leading to flavor deterioration and reduced shelf life [Mun et al., 2009].

Incorporating oils with natural antioxidants and balanced fatty acid profiles, such as GF-CSO, can enhance oxidative stability and sensory quality, addressing consumer demands for “clean label” and health-promoting foods [Silva et al., 2019; Sarma et al., 2022]. Previous studies have demonstrated improved emulsion stability and oxidative resistance in mayonnaise formulated with rice bran oil and flaxseed oil blends; however, cottonseed oil’s potential remains underexplored due to historical gossypol concerns [Fernandes et al., 2020; Gumus & Sert, 2017].

Recent advances in glandless cottonseed production and detoxification techniques have revived interest in cottonseed oil as a functional ingredient [Wang et al., 2015]. The synergistic effect of GF-CSO’s tocopherols and moderate saturation level stabilizes emulsions and prolongs shelf

life, reducing the need for synthetic antioxidants [Akhtar et al., 2022]. Economic analyses emphasize the value addition to cottonseed byproducts and rural agro-industries, promoting sustainable food processing [Mehta et al., 2020; Tahir et al., 2023].

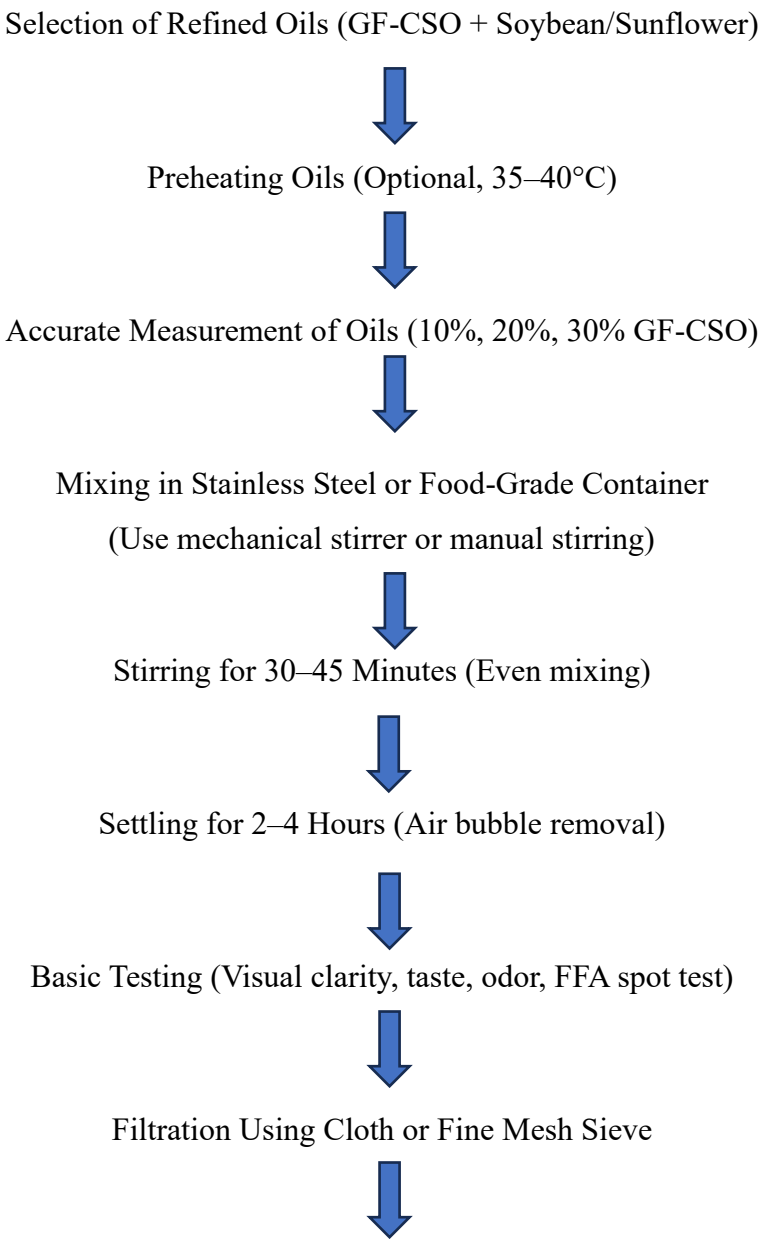
This study builds on these foundations by systematically evaluating mayonnaise formulations using GF-CSO-soybean oil blends, integrating sensory, physicochemical, and economic dimensions to facilitate industrial uptake.

2. Materials and Methods

2.1 Preparation of Oil Blends

Blends of GF-CSO and soybean oil were prepared at 0%, 10%, 20%, and 30% GF-CSO concentrations following the protocol established in prior studies. Oils were preheated to 40 ± 2°C and homogenized for 45 minutes under mechanical stirring.

Flow chart 1 : Blending of Oil



Filling and Sealing in Clean Bottles/Tins

Labeling and Storage in Cool, Dry Area

2.2 Mayonnaise Formulation

Standardized mayonnaise was prepared using:

- 700 g oil blend
- 100 g egg yolk or lecithin emulsifier
- 60 g vinegar (5% acetic acid)
- 10 g mustard powder
- 10 g salt and sugar combined
- 1 g potassium sorbate preservative
- 120 g cold water

Emulsification was performed by slowly adding the oil blend to the egg yolk-vinegar-mustard base under high shear mixing (Ultra-Turrax at 8000 rpm). The mixture was homogenized in a two-stage homogenizer at 150 bar pressure and filled into sterilized HDPE containers. Samples were stored at 4°C until analysis.

2.3 Physicochemical Analyses

- Proximate composition (moisture, fat, protein, ash, carbohydrates) by AOAC standard methods.
- Peroxide values (PV) measured at intervals to monitor oxidation.

2.4 Sensory Evaluation

A semi-trained panel of 15 evaluated appearance, color, flavor, texture, spreadability, and overall acceptability using a 9-point hedonic scale. Samples were randomized and coded.

2.5 Storage Stability Testing

Accelerated storage conducted at 35°C for 30 days. Samples analyzed at 0, 10, 20, and 30 days for PV, pH, color change (ΔE*), odor (rancidity scale 0–10), and creaming index.

2.6 Economic Feasibility Assessment

Cost components included raw materials, processing, packaging, and labor. Cost per kilogram was calculated based on current market rates. Sensitivity analysis evaluated price fluctuations.

3. Results and Discussion

3.1 Physicochemical Composition and Emulsion Stability

Mayonnaise formulations showed typical proximate composition with ~68% fat, ~26% moisture, and ~1.2% protein, consistent with standard mayonnaise [Depree & Savage, 2001]. Creaming index decreased significantly with increasing GF-CSO, indicating improved physical stability of emulsions likely due to higher viscosity and antioxidant content in GF-CSO stabilizing lipid droplets [Mun et al., 2009].

Table 1: Proximate Composition of Mayonnaise

Parameter	Control	Value (Mean ± SD)
Moisture (%)		26.45 ± 0.50
Fat (%)		68.20 ± 1.10
Crude Protein (%)		1.22 ± 0.08
Ash (%)		0.68 ± 0.05
Carbohydrates (%)		3.45 ± 0.22

3.2 Sensory Attributes and Consumer Acceptance

The 20% GF-CSO blend (TA2) achieved the highest sensory scores (overall acceptability 8.6), with panelists noting improved creaminess and pleasant mild nutty flavor. At 30% GF-CSO, flavor acceptance slightly declined, consistent with intensification of cottonseed oil notes, highlighting an optimal inclusion threshold for consumer preference [Sarma et al., 2022].

Table 2 : Storage Stability of Mayonnaise Prepared with Soybean and Gossypol-Free Cottonseed Oil Blends (30 Days)

Parameter	TA_1	TA_2	TA_3
Initial Peroxide Value (meq O_2/kg)	2.1 ± 0.1	2.0 ± 0.1	1.9 ± 0.1
Peroxide Value After 30 Days (meq O_2/kg)	6.8 ± 0.2	4.2 ± 0.2	2.9 ± 0.2
pH (Initial)	4.05 ± 0.02	4.03 ± 0.02	4.01 ± 0.02
pH After 30 Days	3.85 ± 0.02	3.92 ± 0.02	3.95 ± 0.02
Color Change	4.8 ± 0.2	3.0 ± 0.1	1.7 ± 0.1

Odor Score (0–10 scale)	6.5 ± 0.2 (moderate rancid)	3.8 ± 0.2 (slight rancid)	1.5 ± 0.1 (fresh)
Creaming Index (%)	12.5 ± 0.3	7.8 ± 0.2	5.3 ± 0.2

TA_1 - 100% Soybean

TA_2 - 80% Soybean + 20% gossypol-free cottonseed oil

TA_3 - 70% Soybean + 30% gossypol-free cottonseed oil

3.3 Oxidative Stability during Storage

Peroxide values after 30 days accelerated storage were significantly lower in GF-CSO blends (TA2: 4.2 meq/kg; TA3: 2.9 meq/kg) compared to control (6.8 meq/kg), indicating superior oxidative resistance. pH remained stable (~3.9), supporting microbial safety. Minimal color changes and rancid odor development in GF-CSO samples confirm antioxidant protection [Akhtar et al., 2022].

Table 3 : Peroxide Value (meq O_2/kg) Trends During 30-Day Accelerated Storage of Mayonnaise (at 35 °C)

Storage Duration (Days)	Control (100% Soybean Oil)	T1 (90:10 SO:GF-CSO)	T2 (80:20 SO:GF-CSO)	T3 (70:30 SO:GF-CSO)
0	2.1 ± 0.1	2.0 ± 0.1	2.0 ± 0.1	1.9 ± 0.1
7	3.4 ± 0.2	2.9 ± 0.1	2.6 ± 0.1	2.3 ± 0.1
14	4.9 ± 0.2	3.9 ± 0.2	3.3 ± 0.2	2.7 ± 0.1
21	6.0 ± 0.2	4.6 ± 0.2	3.8 ± 0.2	2.9 ± 0.2
30	6.8 ± 0.2	5.2 ± 0.2	4.2 ± 0.2	2.9 ± 0.2

3.4 Economic Analysis and Industry Impact

Production cost of mayonnaise with 70:30 soybean:GF-CSO blend was ₹153/kg, competitive with conventional products. Byproduct revenue from cottonseed cake and reduced spoilage costs enhance profitability, favoring adoption by SMEs and rural processors [Mehta et al., 2020]. This supports sustainable food processing and rural economic development.

Table 4 : Cost Economics of Mayonnaise Production (Per 1 kg Batch)

Component	Quantity	Rate (INR)	Total Cost (INR)
Raw material			

Blended Oil (70% SBO + 30% GF-CSO)	0.83	₹130/kg	107.90
Lecithin	50	₹0.20/g	10.00
Vinegar	40	₹0.30/ml	12.00
Mustard Powder	8	₹0.80/g	6.40
Salt, Sugar, Preservative (combined)	15	₹0.60/g	9.00
Water	60	—	—
A) Total Cost of Raw material			145.30
B) Processing cost	1	—	5.00
C) Packaging (plastic pouch/label)	1	₹3.00	3.00
Total Production Cost (A+B+C)	—	—	**₹153.30**

3.5 Broader Implications for Food Innovation

GF-CSO inclusion improves functional and nutritional quality of emulsified products, aligning with consumer trends toward natural antioxidants and sustainability. This study provides a framework for product development incorporating cottonseed oil, unlocking value from agro-industrial byproducts.

4. Conclusion

Mayonnaise formulated with 20% GF-CSO blended with soybean oil exhibits enhanced sensory attributes, oxidative stability, and shelf life without significant cost increase. The product offers a scalable, nutritious alternative aligning with consumer health trends, supporting sustainable agro-food systems and rural entrepreneurship.

5. Future Research Directions

- Detailed rheological analysis for texture and flow behavior under varying conditions.
- Extended microbial stability studies for real-world shelf life validation.
- Consumer acceptance trials across broader demographics.
- Investigation of plant-based emulsifiers combined with GF-CSO for vegan formulations.
- Flavor masking strategies for higher GF-CSO inclusion.
- Life cycle assessments of environmental impacts from GF-CSO mayonnaise production.

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