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Development and quality evaluation of soy based coffee analogue

Richa Soni[1], Tarun Yogi[2*], Helly Patel[3], Hemali Chauhan[4]
[1, 2, 3, 4, 5] Department of Life Science and Food Science and Nutrition
University School of Science
Gujarat University, Ahmedabad, Gujarat, India
*Corresponding author's Email: tarunyogi98@gmail.com

ABSTRACT
The aim of this investigation was to create a soy-based substitute for coffee and assess its nutritional, anti-nutritional properties, sensory characteristics, and consumer acceptability in contrast to commercial coffee powder. The soybeans were treated with 1% $NaHCO_3$ and then dried at room temperature. Three different roasting methods were employed: sand roasting for three hours at 80˚C, salt roasting for three hours at 80˚C, and salt roasting for one hour at 160˚C. The finest quality powder was obtained by roasting salt for one hour at 160˚C. The 1:1 combination of roasted soybean powder and robusta coffee powder was used to create the soy-based coffee analogue. Soy coffee powder was used to create three products, including hot coffee, cold coffee, and coffee-flavored ice cream (kulfi). The nutritional content, anti-nutritional constituents (tannin and phytic acid), and sensory characteristics were assessed using standard procedures. The study indicates that soy coffee had considerably higher protein, fat, carbohydrate, and energy than commercial coffee powder ($p<0.05$). Hot coffee, cold coffee, and ice cream (kulfi) were all accepted by consumers to varying extents (85.66%, 89.44%, and 95.33%, respectively). Also, the caffeine level of the developed soy coffee powder was much lower (687.87±33.61 ppm) than that of commercial coffee powder (1609.18±31.83 ppm) ($p<0.05$). The quantity of phytic acid (43.5 mg) and tannin (24.4 mg) in the soy-based coffee analogue was much lower after boiling and roasting compared to the quantities of phytic acid (300 mg) and tannin (42.2 mg) in raw soybean, according to the assessment of anti-nutrient factors.
Keywords: *Coffee, coffee analogue, caffeine, tannin, phytic acid*

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INTRODUCTION

According to Samoggia and Riedel (2018), coffee is currently one of the most popular beverages worldwide [1]. According to the Coffee Market Report of 2021, the global coffee market had a value of USD 102.02 billion in 2020 and is expected to grow at a compound annual growth rate of 4.28% between 2021 and 2026 [2]. According to several recent studies, caffeine may be harmful to people's health. It can reduce appetite [3], be linked to abortion, preterm delivery, and foetal growth restriction [4], cause restlessness and insomnia [5], cause breast tissue cysts in females [6], incontinence [7], and cause digestive problems [8]. Moreover, it may decrease fertility in both men and women [9], cause allergies and miscarriage [10], trigger strong heart contractions [11], anxiety, depression, and the need for anxiety medication [12], reduce collagen production in human skin [13], interfere with ossification, and increase the risk of bone fractures [14].

By raising peripheral vascular resistance, caffeine causes a rise in blood pressure. The risk of getting hypertension increased moderately with daily coffee consumption between one to three cups [15]. The literature reports the hazards of elevated hypertension in coffee users, and coffee-induced increase in adrenaline levels may cause this vasoconstrictive effect [16, 17].

Coffee appears to increase the incidence of gastrointestinal and colon cancers in men [17]. It is also linked to a higher risk of osteoporosis, gastritis, anaemia, and stillbirths [18]. Caffeine also causes insomnia, elevated heart rate and blood pressure, neurological problems, vasodilation, trembling, seizures, urticaria, headaches, increased body temperature, and behavioural changes [19].

Because there are tremendous health hazards of caffeine, there is an urgent need to find out nutritious substitutes for coffee which can replace coffee powder. Soybeans are a good source of high protein, low in

saturated fat level, and have a good percentage of dietary fibre [20]. Soybean has been shown to have anti-oxidant, anti-diabetic, anti-proliferative, anti-obesity, anti-inflammatory, and anti-proliferative characteristics [21, 22, 23]. Its intake has been linked to several possible health benefits as well as a decrease in a number of chronic conditions like obesity, diabetes, immunological disorders, some forms of cancer, and cardiovascular disease [24]. Since soy protein and dietary fibre appear to lower the risk of cardiovascular disorders and improving glycemic control, the potential application of soy in functional food design is particularly attractive. Coffee has a high content of caffeine which adversely affects health. Therefore, the present investigation is planned to develop soy based coffee analogue.

Several studies have been undertaken in the past to determine the health implications of increased caffeine use in both men and women. Caffeine use is linked to a variety of cardiovascular problems, osteoporosis, sleep issues, and neurological disorders. Coffee use in India has increased dramatically as a result of shifting food consumption trends, lifestyles, and stress-related diseases. There is a tremendous desire to provide consumers with a healthy coffee replacement. As a result, the current study was designed to optimise the process of developing soy coffee and compare it to commercially available coffee in terms of nutrients, anti-nutrients, caffeine, sensory properties, and consumer acceptability. The overall objective of the study was to develop a coffee analogue with more protein and less caffeine content, to compare the nutritional composition of developed soy coffee and commercial coffee powders, to evaluate anti-nutritional factors in developed coffee analogue, and to assess consumer acceptability of products developed with coffee analogue.

MATERIAL AND METHODS

Sample collection: For the study soybeans (*Glycine max*) were purchased in a single lot from the local store of Ahmedabad. Robusta roasted coffee beans were ordered online from Chikmagalur, Karnataka.

Development of coffee analogue

For the development of soy coffee, firstly impurities and foreign materials were removed and soybeans were washed. Washed soybeans were boiled in water with 1% $NaHCO_3$ (soybean to water ratio 1:3) for 5 minutes. After removing the water and skin of soybeans, they were dried at room temperature for 72 hours. $NaHCO_3$ treated beans was subjected for roasting by 3 different methods:

I. Sand roasting (3 hours - 80º C temperature) (1:10 soybean to sand ratio)
II. Salt roasting (3 hours - 80º C temperature) (1:10 soybean to salt ratio)
III. Salt roasting (1 hours - 160º C temperature) (1:10 soybean to salt ratio)

The roasted beans were then allowed to cool down at room temperature and then ground into the mixture. A 40 mesh sieve (0.42 mm) was used to strain the powdered beans. The $NaHCO_3$ treated and roasted soybean powder was then mixed with procured Robusta coffee powder with the ratio of 1:1.

Assessment of proximate of developed soy based coffee analogue

According to the protocols set forth by the Association of Official Analytical Chemists [25], the sample's proximate components, such as moisture, ash, protein, fat, and carbohydrates were all examined. After burning out all non-mineral stuff in a muffle furnace with the dried samples, the ash was measured. The Kjeldahl digestion method and a nitrogen conversion factor of 6.38 were used to determine the protein content [26]. The Mojonnier method for fat analysis was used to test fat. By calculating the difference between the total solids and the other solid components, the amount of carbohydrates was obtained. Utilizing the acid and alkali hydrolysis method, crude fiber was measured.

Estimation of anti-nutritional factors and caffeine

The phytic acid concentration was determined by the rapid colorimetric procedure based on the reaction between ferric ion and sulfosalicylic acid [27]. Tannin content was measured using vanillin assay outlined by Price et al., 1978 [28]. The UV/Vis spectrophotometry method recommended by Wanyika et al., 2010 was used to determine the amount of caffeine present in coffee samples [29].

Selection of coffee powder for product development: Soybean powder was chosen based on sensory properties such as aroma, texture, flavour, appearance, taste, and solubility. Based on all of the characteristics, 1:10 salt-roasted soybeans (1 hour at 160 °C) were chosen for the coffee analogue formulation. Soy powder and commercial coffee powder were mixed in three different ratios: 7:3, 6:4, and 1:1. For product formulation, a 1:1 bland sample was used.

Formulation of products

All the products were formulated from blend of commercial coffee beans and $NaHCO_3$-treated and salt-roasted beans in a ratio of 1:1. For the formulation of hot coffee, 250 ml of milk and 7.5 g of sugar were added to the pan and boiled for three minutes. Then 7.5 g of coffee analogue powder was added and again boiled for two minutes before being sieved into a coffee mug. To formulate cold coffee, 250 ml of milk, 22.05 g of sugar, and 7.5 g of coffee analogue powder were added to the pan, churned with a hand mixer, and then

sieved into a coffee mug. For the preparation of ice cream (kulfi), 1 litre of milk was taken and 100 g of sugar was added to it. Then boil it till the consistency becomes thick and it turns a light yellow in color. It was kept at 0 ˚C for 12 hours. After 12 hours, 5 g of coffee analogue powder and 5 g of almond (small pieces) were added to it and kept it in the candy tank for 15-20 minutes. After that, store it in cold storage at a temperature of -25 to -30 ˚C.

Sensory evaluation and consumer acceptability

The sensory evaluation was carried out to assess various aspects such as colour, appearance, consistency, aroma, taste, flavour, and overall acceptability. In the laboratory of the department of food science and nutrition, sensory evaluations of prepared items were scored using a nine-point hedonic scale ranging from extremely like to extremely dislike (9 = like extremely, 1 = dislike extremely) [30]. Selected panel members conducted sensory evaluation. The panel members were selected with the help of sensitivity threshold test**.** A group of 25 panel members for hot coffee, 32 panel members for cold coffee, and 50 panel members for ice cream (kulfi) were selected.

Statistical analysis

Mean, standard deviation and standard error were calculated for the nutritional and anti-nutritional composition of coffee analogue and commercial coffee powder. The student's t-test was used to assess the difference in quality parameters between coffee analogue and commercial coffee powder in nutrition, anti-nutritional and consumer acceptability. SPSS (17.0) [Chicago, USA] was used for statistical analysis. The P-value ($p<0.05$) was considered as statistical significance.

RESULTS

Table I shows the nutrient content of developed soy coffee powder and commercial Robusta coffee powder. This developed soy based coffee analogue powder contains 2.01 % moisture, 7.37 g fibre, 16.7 g fat, 4.76 g ash, 24.44 g protein, 44.73 g carbohydrate and 426.98 Kcal energy while commercial Robusta coffee powder contains 4.21 % moisture, 5.29 g fibre, 8.31 g fat, 2.01 g ash, 8.78 g protein, 54.29 g carbohydrate and 327.07 Kcal energy.

Figure 2 indicates that raw soybean contains 42.2 mg amount of tannin and 1-hour salt-roasted soybeans have 24.4 mg amount of tannin and the amount of phytic acid in raw soybean and in 1-hour salt-roasted soybeans was respectively found to be 300 mg and 43.5 mg.

Therefore, we can conclude that the amount of tannin and phytic acid in the soy based coffee analogue is significantly lower than raw soybeans.

According to Table 2, the developed soy coffee powder and commercial coffee powder had caffeine concentrations of 687.87 ppm and 1609.18 ppm, respectively. Therefore, it can be concluded that the developed soy coffee powder has significantly less caffeine than commercial coffee powder ($p<0.05$).

Organoleptic qualities of developed coffee products

Sensory evaluation was performed to check the acceptability of developed products. Figure 3 indicates that overall acceptability of hot coffee, cold coffee and ice cream (kulfi) were 7.71, 8.05 and 8.58 respectively. These results revealed that ice cream (kulfi) was the most accepted product of all three products.

The results from the salt roasting for one hour at 160˚ C method are shown above. They include the acceptability index (percent), minimum overall acceptability score, and maximum overall acceptability score of a developed product. Hot coffee had an acceptance rate of 85.66 percent. The minimum and maximum scores for overall acceptance in hot coffee were 4 and 9, respectively. The cold coffee acceptability index was 89.44 percent, with a minimum score of 7 and a maximum score of 9. 95.33 percent of panel members accepted the ice cream (kulfi), with a minimum score of 7 and a maximum score of 9. Total 25 observations were taken for the sensory evaluation of hot coffee, 32 observations were taken for cold coffee and 50 observations were taken for ice cream (kulfi). Here we can observe that the cold coffee has a higher acceptability than the hot coffee and ice cream (kulfi) has higher acceptability than both cold coffee and hot coffee.

DISCUSSION

Coffee is among the world's most popular beverages. Coffee is made from coffee beans. Coffee is also known as an energy drink because it eliminates lethargy in our body [31]. Coffee, in addition to being a stimulant, has a distinct aroma and antioxidant content (CGA). Caffeine, on the other hand, has detrimental health consequences. Caffeine use can also cause hypertension, anxiety, and tachycardia [32].

A coffee analogue is a non-caffeine product that is used to modify coffee drinks without changing the overall flavour of coffee [33]. The roasting procedure used on coffee analogues is essential for achieving aroma and flavour characteristics similar to coffee [34]. Soybean is high in nutrients and has several health benefits. It is also utilised as an adulterant in commercially available coffee [35]. As a result, we made an effort to

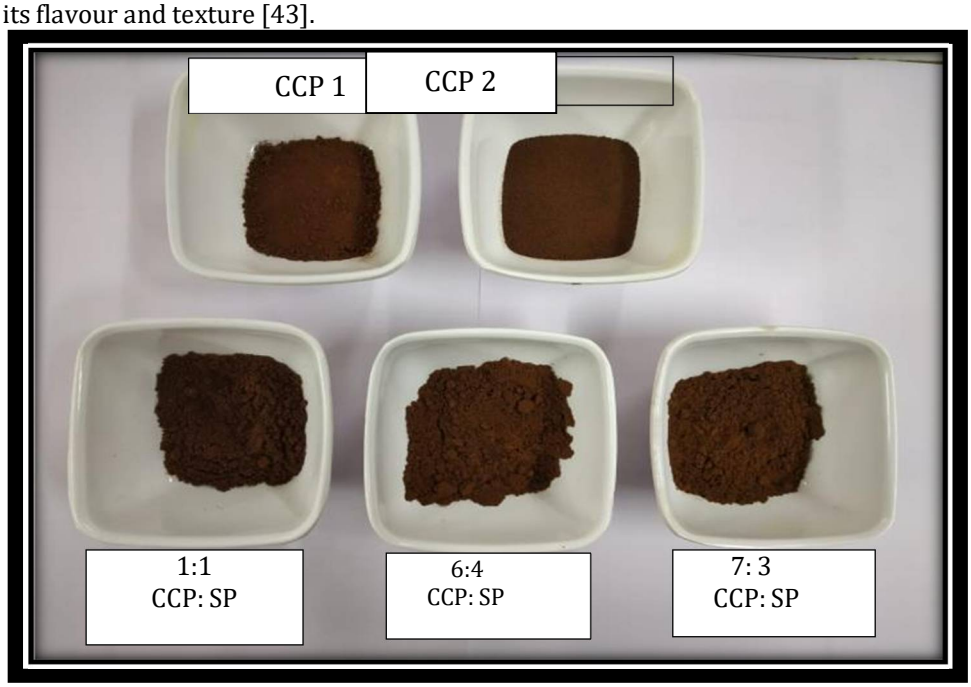
formulate a soy-based coffee analogue that is identical to commercially available coffee in terms of colour, appearance, flavour, aroma, taste and consistency.

The proximate composition is an important characteristic for determining the quality of raw materials. In the present study, we have observed that developed soy based coffee analogue has significantly higher amount of fibre, fat, protein, carbohydrate and energy value as compared to commercially available robusta coffee ($p<0.05$). While carbohydrates are source of energy, fibre is a crucial component of a diet that is required for digestive health [36]. This suggests that, when it comes to proximate composition, soy based coffee analogue is superior to robusta coffee.

Vegetables naturally contain the polyphenolic compounds known as tannins. Tannin has antinutritional properties because it forms complexes with small nutrients like phosphorus, calcium, magnesium, and others as well as significant nutrients like carbohydrates and proteins, making them unavailable for utilisation by the body [37, 38]. Moreover, it combines with the enzymes needed for the breakdown of pectins, proteins, and carbohydrates, preventing them from functioning and lowering the food's nutritious value [39]. The main source of phosphorus storage in seeds is phytic acid (PA), which accounts for up to 80% of the total phosphorus in seeds and up to 1.5% of their dry weight. Ca, Fe, K, Mg, Mn, and Zn metallic cations are forcefully bound by the negatively charged phosphate in phytic acid, becoming insoluble and unavailable as dietary components [40].

In this study, we found that amount of tannin and phytic acid in soy-based coffee analogue was lower than raw soybean, which indicates that processing methods like boiling and roasting have reduced the amount of anti-nutritional factors like tannin and phytic acid from soybeans. Similar types of results were obtained by (YADAV et al., 2017). Soaking and roasting also increases the protein, carbohydrate, fat, calories as well as overall digestibility by lowering the amount of tannin and phytic acid [41, 42]. The amount of caffeine is also lower in the formulated soy-based coffee analogue than commercial robusta coffee.

Overall acceptability observed in this study was 85.66% for cold coffee, 89.44% for hot coffee and 95.33% for ice cream which were in line with previously conducted study by Khider et al., 2021 who found that compared to using Nescafe and other coffee powders, adding 3% roasted date seed powder to ice cream enhanced its flavour and texture [43].



SCP: Soy coffee powder CCP: Commercial coffee powder

Fig.1 Different ratios of soy powder and commercial coffee powder

Table 1: Nutrient composition of developed soy coffee product and Commercial Robusta coffee beans

Nutrients	Soy coffee powder	Commercial Robusta coffee powder
Moisture (%)	2.01±0.01[a]	4.21±0.50[b]
Fibre (g)	7.37±0.31[a]	5.29±0.29[a]
Fat (g)	16.7±0.59[b]	8.31±0.63[a]
Ash (g)	4.76±0.92[b]	2.01±0.31[a]
Protein (g)	24.44±2.37[b]	8.78±0.21[a]
Carbohydrate (g)	44.73±5.43[a]	54.29±9.24[b]
Energy (Kcal)	426.98±21.20[b]	327.07±15.30[a]

Values with different alphabet within same row differs significantly ($p<0.05$). Student 't' test was used to assess the difference in nutritional composition of two samples.

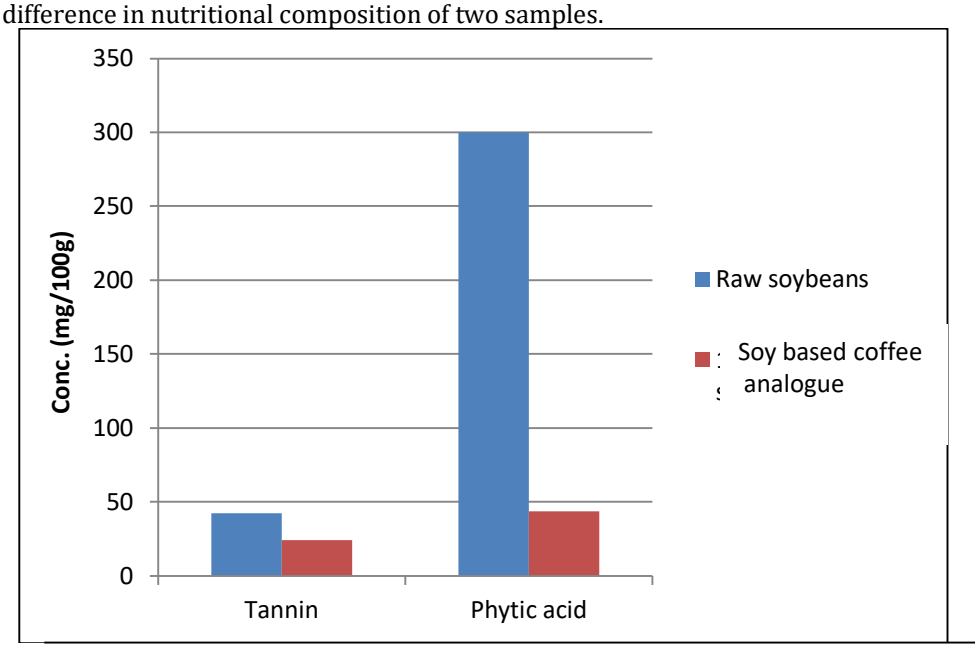
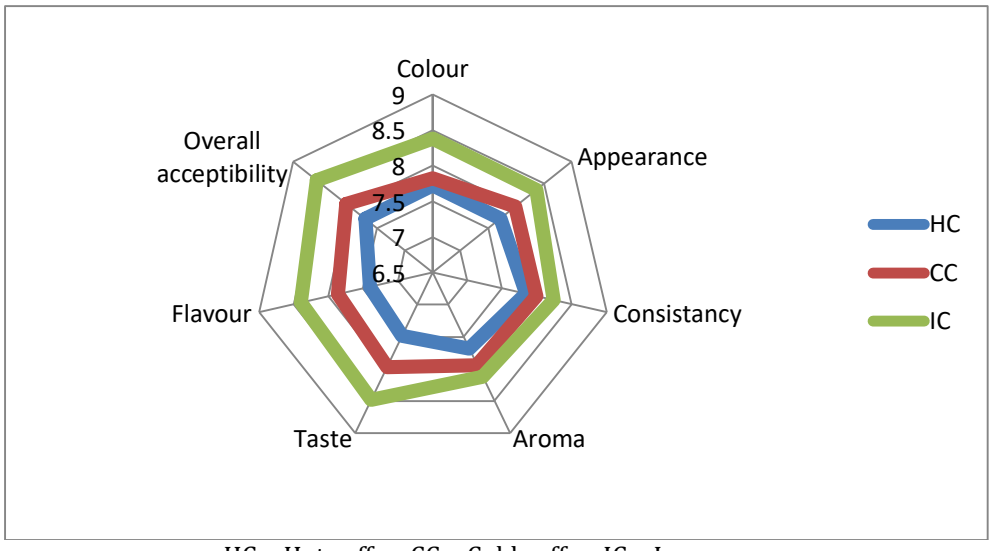


Fig. 2 Comparison of anti-nutritional factors in raw soybeans and soy based coffee analogue

Table 2: Caffeine concentration (ppm) in soy coffee and commercial coffee Powder

Sr. no	Sample	Caffeine conc. (ppm)	P value
1	Soy coffee	687.87±33.61	0.005
2	Commercial coffee powder	1609.18±31.83	



HC = Hot coffee, CC = Cold coffee, IC = Ice-cream

Fig. 3. Sensory acceptability of developed products

Table 3: Details of sensory analysis of developed product

Processing	Product	No. of observation	Average Score	SD	Min Score	Max Score	Acceptability index %
Salt	Hot	25	7.71	0.13	4	9	85.66%[a]
roasting for	coffee						
1 hour at	Cold	32	8.05	0.35	7	9	89.44%[b]
160˚ C	coffee						
	Ice	50	8.58	0.60	7	9	95.33%[c]
	cream						
	(kulfi)						

Acceptability index (%) = overall acceptability score * 100 / 9 (maximum score)

Values with different alphabet within same column differs significantly ($p<0.05$). Student 't' test was used to assess the difference in nutritional composition of two samples.

CONCLUSION

Overall it can be concluded that $NaHCO_3$ treatment and salt roasting at 160˚C temperature for one hour was found to be the best method to develop soy powder which resembles in aroma and flavour of the Robusta coffee powder. Therefore the roasted soybean powder obtained from the above mentioned process can be successfully used to develop a coffee analogue with a ratio of 1:1 with Robusta coffee powder without compromising the taste, appearance and aroma of the coffee.

The coffee substitute made from soybeans was discovered to be significantly more nutritionally balanced than commercial coffee powders, with higher protein and mineral content and lower caffeine content ($p<0.05$). When compared to raw soybean, the anti-nutritional factors were found to be significantly lower. Coffee-flavored ice cream, hot coffee, and cold coffee can all be made using the newly created soy coffee powder. The sensory qualities of the products made with soy coffee powder scored higher than 7.0 on a hedonic scale with little variation, indicating that consumers liked all three of the finished products. Hot coffee had a consumer acceptability index of 85.66 percent, cold coffee had an acceptability index of 89.44 percent, and ice cream had an acceptability index of 95.33 percent.

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