RESEARCH PAPER

Optimization of Biofortification Process for Solar Salt Using Herbal Extracts

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ABSTRACT

The fortification of salt with medicinal plants offers a promising approach to enhance its nutritional and therapeutic value. The present study explores the potential of incorporating bioactive compounds from medicinal plants into salt, focussing on their health benefits and technological feasibility. Salt samples were collected from three different salt-pans in Tuticorin district namely Tharuvaikulam, Kallurani and Melmandhai. Tharuvaikulam and Kallurani utilize sub-soil brine for salt production whereas Melmandhai uses sea brine for salt production. Medicinal plants such as Red amaranth, Keezhanelli and Pigweed leaves which are rich in anti-oxidants, antimicrobials and anti-inflammatory compounds can be used to fortify salt providing a functional food that promotes health beyond basic nutrition. The fortified salt can be used as a value-added product, promoting the prevention and management of chronic diseases and supporting public health initiatives.

Keywords: Fortification, Salt-pans, Herbal extracts, Micronutrients, Chronic illness

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INTRODUCTION

Fortification is a public health strategy that involves adding essential micronutrients like vitamins and minerals to food or condiments to improve their nutritional value. It's a cost-effective method, particularly for addressing iron and iodine deficiencies, as salt is universally consumed. Levinson and Berg [1] first proposed the idea of multiple fortification through salt in 1969. Their idea later led to the concept of dual fortification of salt with iron and iodine in the 1970's and was published by Narasinga Rao in 1994 [2]. Iodine deficiency disorders (IDD) and Iodine deficiency anaemia (IDA) have affected two billion people in developing countries. Double fortified salt (DFS) contains both iron and iodine, aiming to prevent iron deficiency anaemia and iodine deficiency disorders [3]. Fortified salt is a crucial tool in the fight against micronutrient deficiencies and the addition of essential micronutrients like iodine, iron and folic acid to salt can significantly improve public health.

Biofortification is the process of enhancing the nutritional content of crops, particularly staple foods, through breeding, genetic modification or some other techniques. The goal is to increase the levels of essential micronutrients like vitamins and minerals in crops, making them more nutritious for human consumption. The medicinal plants used for biofortification technique are as follows:

1. Amaranthus Cruentus (Red amaranth)
2. Phyllanthus Niruri (Keezhanelli)
3. Amaranthus Spinosus (Pigweed)

DESCRIPTION ABOUT THE PLANT

1. AMARANTHUS CRUENTUS [RED AMARANTH]

Amaranthus cruentus leaves, commonly known as amaranth, is rich in several essential nutrients. It is a good source of protein, fibre, antioxidants, vitamins and minerals. Amaranth is also notable for its high content of lysine and methionine, which are essential amino acids that are often lacking in other grains. Amaranth is rich in minerals like iron, magnesium, potassium, calcium, copper, phosphorus, zinc and manganese. Red amaranth has been used to treat gastrointestinal issues, heavy menstrual bleeding, bad cholesterol levels and skin infection [4]. It has anticancer properties due to the presence of lunasin, a peptide that can inhibit cancer cell growth.

2. PHYLLANTHUS NIRURI [KEEZHANELLI]

Phyllanthus niruri is an important medicinal plant in traditional medicine. It is a medicinal remedy for stomach, liver disease, kidney stones and spleen. The plant phyllanthus niruri is

traditionally called as the "stone breaker," which has already been used to treat and get rid of kidney stones. Research confirms that this happens "Due to the prevention of calcium oxalate crystal formation and also by dissolving established crystal" [5]. The whole plant is beneficial in gastritis, diarrhea, dysentery, recurrent fevers, ophthalmopathy and scabies. More recently, modern research has included insulin tropic, antioxidant and anti-inflammatory properties such as potentially being new remedies for diabetes, oxidative damage and even chronic inflammatory diseases [6].

3. AMARANTHUS SPINOSUS [PIGWEED]

Amaranthus spinosus, is commonly known as Pigweed. This plant is used as vegetable, ornamental plant and other species are utilized as food, leaf vegetables and cereals cultivated throughout India, Sri Lanka and many tropical countries [7]. It is used for laxative action and also possesses good diuretic property. The seed are also used internally for the treatment of internal bleeding, diarrhoea and excessive menstruation and externally as poultice for broken bones. Whole plant of pigweed is used as a diuretic, purgative, refringent and to treat cholera, piles and snake bite [8]. In Nepal and India, certain tribes use this plant to induce abortion. The decoction of the root is employed to treat gonorrhea, externally applied as an emmenagogue and antipyretic. In Malaysia, it is known for its beneficial effects in acute bronchitis to relieve breathing and as an expectorant [9]. The ash of plant is also used as salt by certain tribes [10].

MATERIALS AND METHODS

PREPARATION OF BIOFORTIFIED SALTS

About 100 gm of raw leaves were boiled in 50 ml of water to obtain the extract. To 10 ml of the above extract, 5 gm each of salt obtained from the three different salt-pans viz. Tharuvaikulam, Kallurani and Melmandhai were added separately to make a homogeneous solution. The solution was evaporated to obtain the fortified salt and the salt samples were recrystallized, dried and weighed separately.

The three salt samples obtained by fortification with Red amaranth leaves were named as **FT1, FK1** and **FM1**. The salt samples that were obtained by fortification with Keezhanelli leaves were named as **FT2, FK2** and **FM2**. The salt samples that were obtained by fortification with Pigweed leaves were named as **FT3, FK3** and **FM3**.

Here T, K, M represent the three salt-pans namely Tharuvaikulam, Kallurani and Melmandhai respectively.

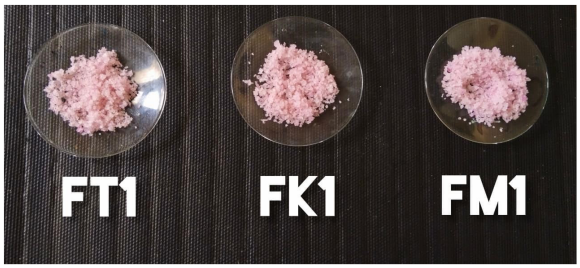

FIGURE 4: FORTIFIED SALTS USING RED AMARANTH LEAVES

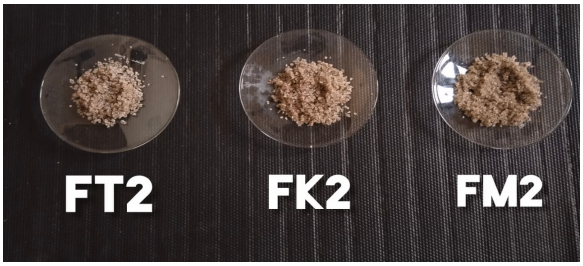

FIGURE 5: FORTIFIED SALTS USING KEEZHANELLI LEAVES

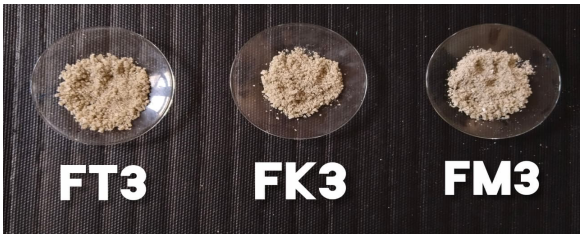

FIGURE 6: FORTIFIED SALTS USING PIGWEED LEAVES

TABLE 1: WEIGHT OF FORTIFIED SALTS

The chemical composition of salt before fortification is given in table-2.

Table 2: Chemical composition of salts before fortification

INGREDIENTS	THARUVAIKULAM	KALLURANI	MELMANDHAI
5g salt + 10 ml of red amaranth leaf extract	**FT1** 1.930	**FK1** 1.947	**FM1** 1.922
5g salt + 10 ml of keezhanelli leaf extract	**FT2** 1.845	**FK2** 1.976	**FM2** 1.957
5g salt + 10 ml of pigweed leaf extract	**FT3** 1.917	**FK3** 1.939	**FM3** 1.921

NUTRIENTS	THARUVAIKULAM	KALLURANI	MELMANDHAI
Calcium (%)	0.46	0.43	0.36
Magnesium (%)	0.26	0.25	0.17
Sodium (%)	1.55	1.52	1.49
Potassium (%)	0.058	0.051	0.047

The fortified salt samples were examined for various nutrients like calcium, magnesium, sodium and potassium using standard procedures and the results are provided in table- 3.

TABLE 3: CHEMICAL COMPOSITION OF SALTS AFTER FORTIFICATION

Medicinal Leaves	Sample	Calcium (%)	Magnesium (%)	Sodium (%)	Potassium (%)
Red Amaranth	FT1	0.63	0.51	1.60	0.096
	FK1	0.58	0.47	1.56	0.089
	FM1	0.49	0.42	1.53	0.084
Keezhanelli	FT2	0.61	0.38	1.57	0.106
	FK2	0.58	0.36	1.54	0.102
	FM2	0.50	0.29	1.52	0.097
Pigweed	FT3	0.84	0.53	1.64	0.121
	FK3	0.81	0.50	1.61	0.115
	FM3	0.76	0.46	1.58	0.109

RESULTS AND DISCUSSION

COMPARATIVE STUDY OF CHEMICAL PARAMETERS OF SALTS FORTIFIED USING MEDICINAL PLANTS [TABLE 3]

CALCIUM (%)

The percentage of calcium for the salt fortified using red amaranth leaves were found to be 0.63, 0.58 and 0.49 for the samples FT1, FK1 and FM1 respectively. The percentage of calcium for the samples of FT2, FK2 and FM2 which were fortified with keezhanelli leaves were found to be 0.61, 0.58 and 0.50. The percentage of calcium for the samples of FT3, FK3 and FM3 which were fortified with pigweed leaves were found to be 0.84, 0.81 and 0.76. Among the three samples of fortified salts,

- The maximum percentage of calcium content was found to be 0.84 and it was observed in the sample FT3.
- The minimum percentage of calcium content was found to be 0.49 and it was observed in the sample FM1.

MAGNESIUM (%)

The percentage of magnesium for the salt fortified using red amaranth leaves were found to be 0.51, 0.47 and 0.42 for the samples FT1, FK1 and FM1 respectively. The percentage of magnesium for the samples of FT2, FK2 and FM2 which were fortified with keezhanelli leaves were found to be 0.38, 0.36 and 0.29. The percentage of magnesium for the samples of FT3, FK3 and FM3 which were fortified with pigweed leaves were found to be 0.53, 0.50 and 0.46.

Among the three samples of fortified salts,

- The maximum percentage of magnesium content was found to be 0.53 and it was observed in the sample FT3.
- The minimum percentage of magnesium content was found to be 0.29 and it was observed in the sample FM2.

SODIUM (%)

The percentage of sodium for the salt fortified using red amaranth leaves were found to be 1.60, 1.56 and 1.53 for the samples FT1, FK1 and FM1 respectively. The percentage of sodium for the samples of FT2, FK2 and FM2 which were fortified with keezhanelli leaves were found to be 1.57, 1.54 and 1.52. The percentage of sodium for the samples of FT3, FK3 and FM3 which were fortified with pigweed leaves were found to be 1.64, 1.61 and 1.58.

Among the three samples of fortified salts,

- The maximum percentage of sodium content was found to be 1.64 and it was observed in the sample FT3.
- The minimum percentage of sodium content was found to be 1.52 and it was observed in the sample FM2.

POTASSIUM (%)

The percentage of potassium for the salt fortified using red amaranth leaves were found to be 0.096, 0.089 and 0.084 for the samples FT1, FK1 and FM1 respectively. The percentage of potassium for the samples of FT2, FK2 and FM2 which were fortified with keezhanelli leaves were found to be 0.106, 0.102 and 0.097. The percentage

of potassium for the samples of FT3, FK3 and FM3 which were fortified with pigweed leaves were found to be 0.121, 0.115 and 0.109.

Among the three samples of fortified salts,

- The maximum percentage of potassium content was found to be 0.121 and it was observed in the sample FT3.
- The minimum percentage of potassium content was found to be 0.084 and it was observed in the sample FM1.

CONCLUSION

The study demonstrates that fortification of edible salt with medicinal leaf powders is a viable and sustainable approach to enhancing the functional and nutritional properties of a commonly consumed food matrix. The incorporation of medicinal leaves resulted in a measurable increase in bioactive constituents including essential minerals and phytochemicals with antioxidant and antimicrobial potential without adversely affecting the fundamental physico-chemical characteristics of the salt. The presence of naturally derived bioactive compounds suggests potential health benefits such as improved micronutrient intake and protection against oxidative stress, thereby contributing to the prevention of nutrition- related disorders. Overall, medicinal leaf- based salt fortification offers a cost-effective, eco- friendly alternative to conventional fortification strategies and supports the development of functional foods using natural resources. Future investigations are recommended to evaluate nutrient bioavailability, shelf- life stability, toxicological safety and clinical efficacy in order to facilitate large- scale application and regulatory approval.

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