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Study the effect and properties of spray dried grain amaranth malted milk powder

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Abstract
Grain amaranth has high nutritional value, contain higher protein (16-18%) than cereal grains and has significantly higher lysine content. A study was conducted on formulation of spray dried grain amaranth based malted milk powder. Grain amaranth was soaked, germinated, malted and blended with skim milk powder and slurries (20, 25 and 30%) were prepared & spray dried. The optimized grain amaranth malted milk powder had 0.385 g/mL bulk density and color value (L^*, a^*, b^*) of 85.99, 1.10, 13.945, and the moisture, water activity, water solubility, flowability (CI & HR) and pH values were found to be 3.1%, 0.215, 96.32%, (26.1% & 1.353) and 6.32, respectively. The spray dried grain amaranth malted milk powder found to have protein (32%), fat (2%), fibre (1.24%), ash (5.99%) and carbohydrate (60.2%), respectively. The calcium, phosphorus and iron content of malted milk powder was 1200, 820 and 22.8 mg/100 g, respectively. The malted milk powder produced with slurry of 25% concentration had best sensory acceptability upon reconstitution of spray-dried malted milk powder and it was kept for 3 months of storage.

Keywords: Grain amaranth, skim milk powder, spray dryer

Introduction

Grains have generally been classified as either cereal or legume grains. However, seeds of some vegetable for example, amaranth are gaining popularity in some countries because of their high nutritional value and properties which can be used in place of cereals. These seeds are classified as pseudo-cereals. These are seeds or fruits of plants consumed as cereal grains, but are not derived from grasses. These are also included in the list of grains recognized by the International American Association of Cereal Chemists as cereals (Gordon, 2006) [8].

Grown for almost 8,000 years, amaranth has its origins in the Americas (Yarger, 2008) [29]. About 60 different types of *Amaranthus* L. Species can be found in North America; the three most significant species are *Amaranthus caudatus*, *Amaranthus hypochondriacus*, and *Amaranthus cruentus* (Kram and Szot, 1999) [13]. The seeds are typically round, tiny, and categorised as either vegetable or grain types. Both types of seeds are edible and can be used as sources of flour; the grain type's seed is pale, ranging in colour from off-white to pale pink, while the vegetable type's seed is lustrous and black (Yarger, 2008) [29]. According to reports, the seeds are extremely suited to the tropics and can withstand drought, making them a promising crop for increasing food security and availability throughout the African subcontinent (Piha, 1995) [20].

Because of its distinctive agricultural, nutritional, and functional qualities, grain amaranth has the potential to improve population nutrition, particularly in poor nations. It grows quickly, produces a lot, can withstand stress, is nutrient-dense, and has nutraceutical qualities. Proteins, fats, calories, and fibre are abundant in grain amaranth (Muyonga *et al.*, 2008) [16]. When compared to the proteins present in most other plant meals, grain amaranth protein has superior amino acid content. Compared to cereal grains, amaranth grains have higher levels of salt, potassium, calcium, iron, and folic acid, as well as vitamins A, E, and C (Becker *et al.*, 1981) [3]. The presence of polyphenols, anthocyanins, flavonoids, and tocopherols in grain amaranth has been linked to its demonstrated antioxidant potential (Klimczak *et al*., 2002; Escudero *et al*., 2011) [12, 7]. The phenol content of amaranth grains varies among species and can be influenced by external factors (Escudero *et al*., 2011) [7]. Lipid peroxidation is inhibited by the antioxidant activity of phenolics (Charanjit *et al*., 2009) [4].

Grain amaranth is a malting grain of superior grade. It enhances nutritional availability and improves digestibility (Paredes-Lopez *et al.*, 1989) [19]. It is an excellent grain for making malted goods because it is resistant to fungus, aids in the development of alpha and beta amylase during germination, and has a pleasant scent while roasting and kilning. According to Hejazi *et al.* (2016) [9], it possesses some innate characteristics that set it apart from other cereals and millets, making it ideal for malting and creating malted meals.

The grain amaranth malt is traditionally used to make beverages with milk or warm water and sugar. It is also used for baby feeding purposes. This necessitates the creation of a suitable method for spray-drying grains, specifically amaranth, to produce malted milk powder.

Moreover, product perishability and transportation and storage expenses can be decreased by spray-drying grain amaranth to turn it into powder. Since dehydration produces a low moisture content in the product that reduces chemical, physical, and biological degradation of the product, spray drying is one of the most extensively utilised unit operations for extending the shelf life of liquid meals (Salminena *et al.*, 2019) [22]. Moreover, it has a faster rate of moisture removal, more efficient drying, and shorter drying times (Tamime, 2009) [25]. Spray drying is a method that atomizes feed into a hot air stream. This process produces extremely effective heat and mass transfer, which dries the atomized feed in a matter of seconds (Toledo, 2007) [28]. Various spray-dried imitation milk products, such as fortified newborn formula based on peanuts and soymilk powder, have been created in the past. With a steady feed flow rate of 30 mL/min, the spray dryer was working at 200 °C for the intake air temperature and 3 kg/cm2 for the atomization air pressure when the soymilk powder was obtained. Similar to this, spray drying conditions of temperature (130 °C), aspiration (84%), and flow rate (7%), were used to generate fortified infant formula based on peanuts (Dwivedi *et al*., 2014; Kane *et al*., 2010) [6, 11].

A food product's shelf life is commonly understood to be the amount of time following processing and packing that it takes, under carefully controlled storage circumstances, to reach the necessary quality level (Nicoli, 2012) [17]. This necessary standard of quality renders the product fit for human consumption. A typical technique for assessing the stability and quality of a particular food during storage is shelf-life analysis. In actuality, a thorough assessment of shelf life guarantees that customers will receive food that is of the highest calibre (Tian *et al.*, 2019) [27]. In order to make shipping, preservation, and storage easier, the food sector frequently turns liquid items into powder (Nnaedozie *et al.*, 2019) [18].

Food goods can be efficiently packaged to increase their value (Singh *et al.*, 2019) [23]. The product's ability to withstand storage is primarily determined by the packaging material's ability to block gas and moisture. Other factors that affect storage stability include the type of packaging system being utilised, such as vacuum or modified atmosphere packaging. Therefore, taking into account the product's shelf life, choosing the right packing materials is crucial.

There is no information in the literature on the ideal spray drying conditions for malted milk powder or the correct ratio of malted grain amaranth flour to skim milk powder for use in developing a commercially viable product.

Materials and Methods

The main samples of grain amaranth used for the development of malted milk powder were grain amaranth. For the present study, variety of grain amaranth (Suvarna) was collected from the organic farming, UAS, GKVK, Bangalore as shown in Plate1. Skimmed milk powder was collected from local market Bengaluru.

Grain amaranth Malted Powder extraction

The samples are cleaned thoroughly. Clean seeds of grain amaranth, and soaked in water about 25 °C for 12 hrs. The excess water was drained out and seeds are allowed for germination for 12 hrs. The germinated seeds are dried for 4 h. The dried amaranth seeds are roasted for maximizing the nutritional value, and roasted grains are milled (grind) for the malted amaranth powder preparation. The malted seeds are sieved through 60 mesh (250 micron) (B.S.S) and are used to prepare spray dried malted milk powder by following the standard procedure as described by Malleshi and Desikachar (1979) [15].

Spray dried grain amaranth malted milk powder extraction

The malted grain amaranth powder is blended with skim milk powder at different levels (20, 25 and 30%), for wort preparation and homogenized. To achieve best quality product, the spray dryer was operated at predetermined spray drying conditions at different inlet air temperatures (140, 150 and 160 °C) different feed rate to make concentrated slurry (20, 25 and 30%). The Spray dried malted milk powder was collected from stainless steel cyclone in a metalized polyester packaging material. It was packed in pouch and stored at room temperature for further analysis.

The physico-chemical properties and mineral content estimation of spray dried grain amaranth malted milk powder sample were estimated according to the method of AOAC (2016) [1] and AOAC (2005) [2], respectively. A simple hedonic rating test was used for sensory evaluation of spray dried grain amaranth based malted milk powder. The sensory quality attribute *viz.,* color, taste, flavor and overall acceptability were evaluated on nine-point scale, comprises of liked extremely to disliked extremely. The sensory score for each attribute were recorded and statistically analyzed according to procedure described by Ranganna (1991) [21].

Storage condition

The powder obtained after spray drying of grain amaranth malt under the optimized spray drying conditions was used for conducting shelf-life study of the grain amaranth malted milk powder. The powder was stored in packaging material namely, metalized polyester. The shelf -life study was conducted for 3 months in packaging material under ambient condition of 30 – 35 °C and RH 70–80%. Samples of grain amaranth malted milk powder from packaging material were taken at 0^{th}, 15^{th}, 30^{th}, 45^{th}, 60^{th}, 75^{th} and 90^{th} days for analysis. The parameters for evaluation of powder during storage study were moisture content, water activity, bulk density, pH, sensory scores, colour values, microbial load and viability of probiotic microorganism, respectively.

Analysis of powder properties

Moisture content

It was measured by keeping the powder in a hot air oven at 105 °C until constant weight (AOAC, 2016) [1].

$$\text{Moisture content (w.b.)} = \frac{W_1 - W_2}{W_1} \times 100 \quad \text{.Eqn. 1}$$

Where,

W_1 = Initial weight of the sample, g

W_2 = Final weight of the sample, g

Water Activity: For the water activity determination (Hygro Lab C1 bench-top meter), powder was filled in the disposable cups of the water activity meter and the sample drawer knob was turned to open position and the drawer was opened. The prepared sample was then placed in the drawer. Checked the top lip of the cup to make sure that it was free from sample residue (an over filled sample cup may contaminate the chamber's sensors). After placing the sample, reading was noted on the LCD display of the water activity meter.

Bulk Density

The bulk density of spray dried grain Amaranth malted milk powder obtained from different treatments was measured according to the procedure described by Caparino *et al.* (2012) [30] and Lebrun *et al.* (2012) [31].

$$\text{Bulk density (kg/ m}^3\text{)} = \frac{\text{Weight of the Powder (g)}}{\text{Total Powder Volume (mL)}} \text{. Eqn. 2}$$

pH

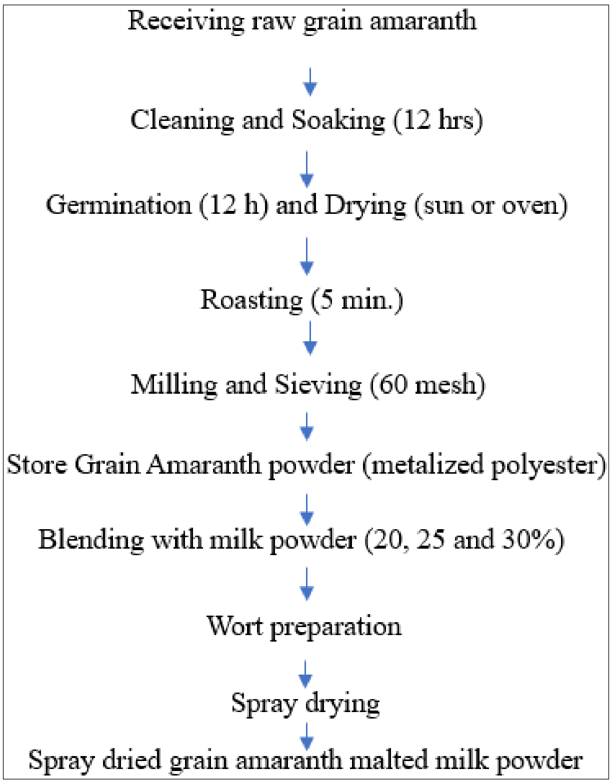
The pH of spray dried grain Amaranth malted milk powders was measured by using digital pH meter. One-gram powdered sample was weighed and it was dissolved in a 10 mL of distilled water in a beaker, then the electrode of the pH meter was dipped in the sample under test. The enter key was pressed to show the pH value and temperature of sample simultaneously (Arab *et al.*, 2011) [32].

Colour: Bench-top spectrophotometer (Model: Konica Minolta; spectrophotometer CM-5) was used for the measurement of colour of grain amaranth. It works on the principle of focusing the light and measuring energy reflected from the sample across the entire visible spectrum. The 3-dimensional scale L^*, a^* and b^* was used. The L^* is the lightness coefficient, a^* represents greenness and redness and b^* represents yellowness and blueness. Once the instrument was standardized, it was ready to measure the colour.

Sensory analysis: The reconstituted grain amaranth malted milk powder samples were served in glasses to a semi trained panel of judges (n = 15) and the panel evaluated the sample for fresh, 15th, 30th, 45th, 60th, 75th and 90th days of storage. The products were evaluated for appearance/color, consistency/mouth feel, taste, flavor, after taste, overall acceptability on a 9-point hedonic scale, where 9 = like extremely, 8 = like very much, 7 = like moderately, 6 = like slightly, 5 = neither like nor dislike, 4 = dislike slightly, 3 = dislike moderately, 2 = dislike very much poor, and 1 = dislike extremely (Larmond, 1977) [14]. Sensory shelf-life analysis was also done to evaluate the ideal period for consumption of a product using sensory evaluation of panellists as per the storage duration. Sometimes, physico-chemical properties of a product are not sufficient to judge the quality of a product with respect to the period in which it is consumed. Hence, evaluation of sensory attributes of the product may indicate the best consumption period.

Statistical analysis: The data obtained on effect of inlet air temperature, feed flow tare and total solid on the spray dried grain amaranth malted milk powder characteristics were statistically analysed as per the design (CRD) to determine the significant differences among treatments using OPSTAT Software. The data for the storage studies like moisture content, bulk density, water activity, pH, colour values, microbial analysis and sensory properties of developed products was statistically analyzed according to the design CRD, in order to determine the significant differences in the responses during storage.

Flow chart for preparation of spray dried grain amaranth based malted milk powder



Result and Discussion

The present investigation was planned for the preparation of grain amaranth-based spray dried malted milk powder; its sensory evaluation was also conducted. The physical (Table 1) and chemical (Table 2) properties of raw grain amaranth and spray dried grain amaranth malted milk powder were as follows:

Table 1: Physical properties raw and optimized spray dried grain amaranth malted milk powder

Raw grain amaranth			
Sl. No.	**Parameters**		**Value**
1	Thousand grain weight (g)		0.699
2	Thousand grain volume (mL)		0.765
3	Color	*L**	62.89
		*a**	7.15
		*b**	29.31
4	Density (g/mL)		0.880
Spray dried grain amaranth malted milk powder			
SL. No.	**Parameters**		**Value**
1	Water solubility (%)		96.32
2	Bulk density (g/cc)		0.385
3	Water activity		0.215
4	Flowability	HR	1.353
		CI	0.261
5	Colour	*L**	85.995
		*a**	1.10
		*b**	13.945

Storage studies of spray dried grain amaranth malted milk powder

Moisture content of malted milk powder

One of the most crucial elements in determining the stability and quality of grain amaranth malted milk powder is its moisture level; low moisture content slows down the rate of microbial development and various deteriorative reactions (Ho *et al*., 2019) [10]. Due to the hydrolysis of oil and phospholipids followed by an increase in acidity, powder with a high moisture content is prone to quality degradation at high temperatures (Dios, 1996) [5]. According to several research on food powder storage, spray-dried powders should have an ideal moisture level of 4–7% to ensure stability during storage (Teijeiro, Péreza, Antonia, and Golowczyca, 2018) [26]. The moisture level of the malted milk powder in metalized polyester increased gradually after storage, ranging from 3.29 to 3.42% (Table 3). Because the product is metallized, the moisture content does not alter significantly. For high barrier, film is utilised. As seen in Fig. 1, flexible packaging, metallic yarn, decorative sequins for textiles, etc.

Fig 1: Raw grain amaranth

Table 2: Chemical properties raw and optimized spray dried grain amaranth malted milk powder

Nutrient	Raw amaranth	Malted milk powder
Moisture content (%)	11.51	3.1
Protein (%)	17.00	27.2
Total carbohydrate (%)	60.89	56.7
Fat (%)	7.00	2.0
Ash (%)	3.60	5.99
Crude Fibre (%)	2.59	1.24
pH	7.5	6.32
Selected Mineral (mg/100 g)		
Calcium (Ca)	490	1200
Phosphorus (P)	600	820
Iron (Fe)	17.5	22.8

Water activity of malted milk powder

The stability and shelf life of a product are determined by water activity (aw), which is correlated with the amount of free water present in the sample (Teijeiro *et al*., 2018) [26]. Low water activity extends the shelf life of the product since it is directly linked to microbial development and the acceleration of chemical breakdown. The absorption of water results in an increase in water activity, which shortens the shelf life of items and causes unwanted changes. Malted milk powder's water activity ranged from 0.215 to 0.355. After storing the malted milk powder in metalized polyester packing material for 75 days, there was a significant difference ($p<.05$) in its water activity, as seen in Table 3. The powder's increased moisture content and rising ambient storage temperature may be the causes of its increased water activity. As seen in Fig. 2.

Fig 2: Grain amaranth malted powder

Bulk density of malted milk powder

Malted milk powder's bulk density rose over time, independent of the container material utilised. Dried milk powder and ice cream mix powder both showed increases in bulk density as the moisture level rose. The absorption of moisture during storage may lead to an increase in cohesiveness, which in turn causes an increase in bulk density. As seen in Table 3 and Fig. 3, the bulk density of the malted milk powder ranged from 0.381 to 0.422 g/mL.

Fig 3: Tall type spray drier

pH malted milk powder

A soy powder suspension's pH may potentially alter as a result of lipid oxidation; however, a drop in pH would be anticipated as a result of the release of acidic chemicals (Snyder and Kwon, 1987) [24]. At the beginning of the storage period, the pH was 6.36. The pH steadily dropped during the course of storage. Table 3 revealed that it had dropped from 6.36 to 6.26. as depicted in Fig. 4.

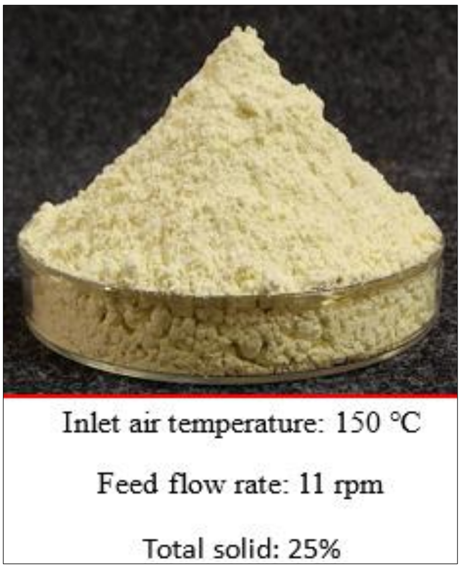


Fig 4: Optimized spray dried grain amaranth malted milk powder

Colour vales of malted milk powder

Fruit, vegetable, and other developed food quality attributes that affect customer acceptability include colour. Table 4 displays colour changes of grain amaranth malted milk powder samples during packaging material storage. The L* and b* values for colour decreased after storage, whereas the a* value increased. The ANOVA results showed that packaging material and storage period significantly (p< 0.05) affected the colour values of malted milk powder. With respect to the package used it was observed that change in colour values was minimum for the powder samples stored. The minimum colour change for the powder may be due to impermeability of air and moisture which favour the reactions responsible for colour change. The change in colour values can be attributed to Maillard reaction. As shown in Fig. 5.

Sensory evaluation of malted milk powder

The sensory scores for the malted milk powder samples during the storage period are given in Fig. 6. It was observed that the overall acceptability of the reconstituted grain amaranth malted milk powder varied from 8.4 to 6.22 on a 9-point hedonic rating scale which indicate that the scores for the sensory parameters dropped marginally throughout the duration of storage. Hence, sensory analysis of malted milk powder after 75th days of storage was decreased. However, there was significant (p<.05) difference in the overall acceptability of malted milk powder (Table 5).

Table 3: Effect of processes parameters during shelf-life study of grain amaranth malted milk

Packaging material	Storage period	Moisture content	Water activity	Bulk density	pH
Metalized polyester	0	3.29	0.215	0.381	6.36
	15	3.33	0.217	0.383	6.354
	30	3.35	0.246	0.385	6.34
	45	3.37	0.292	0.387	6.33
	60	3.39	0.315	0.390	6.29
	75	3.40	0.318	0.416	6.27
	90	3.42	0.355	0.421	6.26
ANOVA	F- value	1.108	214.818	11.028	0.259
	CD@5%	N/A	0.011	0.015	N/A
	SEm ±	0.043	0.004	0.005	0.081
CD: Critical Difference, SEm ±: Standard Error of mean					

Table 4: Effect of storage on colour of spray dried grain amaranth malted milk powder sample stored in metalized polyester (MP) film

Packaging material	Storage period (days)	*L**	*a**	*b**
Metalized polyester	0	86.77	1.12	13.97
	15	86.79	1.45	13.68
	30	87.02	1.61	13.51
	45	87.27	1.72	12.63
	60	87.31	1.734	12.54
	75	87.321	1.745	12.32
ANOVA	90	87.35	1.78	11.9
	F – Value	0.054	134.161	15.704
	CD@5%	N/A	0.059	0.488
	SEm ±	1.111	0.020	0.168
CD: Critical Difference, SEm ±: Standard Error of mean				

Table 5: Effect of packaging material and storage days on sensory characteristics of spray dried grain amaranth malted milk powder

SI. No.	Storage period	Color and Appearance	Texture/ Mouth feel	Flavor/ Aroma	Consistency	Overall acceptability
1	0	8.6	8.5	8.2	8.6	8.4
2	15	8.4	8.3	8.0	8.4	8.2
3	30	7.9	7.8	7.9	7.9	7.8
4	45	7.7	7.6	7.5	7.5	7.5
5	60	7.5	7.5	7.3	7.3	7.2
6	75	7.2	7.3	7.2	7.1	7.0
7	90	6.9	6.5	6.5	6.6	6.2
F – Value		75.276	39.327	43.532	53.134	42.349
CD@5%		0.278	0.254	0.276	0.256	0.263
SEm ±		0.095	0.087	0.095	0.088	0.090
CD: Critical Difference, SEm ±: Standard Error of mean						

Microbial load of malted milk powder

The microbial load of the spray dried malted milk powder was analysed for a period of 90 days starting from 0 days of preparation at an interval of 15 days. The results are presented in Table 6. The *coliforms* were absent in the malted powder throughout storage period. The yeast and molds were absent up to 60 days of storage period and 75th day of storage 0.2 to 0.4 x 10^0 cfu/g. Bacterial count was varied from 0.1 to 1.3 x 10^4 cfu/g during storage period. The findings of the study revealed significant increase in the microbial load in malted milk powder from 75th days of storage at 5% probability level up to 90 days. At 0 days the cfu/g count depicted non-significant increase among all the three types of packaging materials.

Table 6: Effect of storage on microbial load of spray dried grain amaranth malted milk powder sample stored in metalized polyester (MP) film

Storage period (days)	Total plate count (10^4 CFU/g)	Yeast and molds (10^0 CFU/g)	Coliforms (10^0CFU/g)
0	0.1	Nil	Nil
15	0.2	Nil	Nil
30	0.3	Nil	Nil
45	0.4	Nil	Nil
60	0.5	Nil	Nil
75	1.0	0.2	Nil
90	1.3	0.4	Nil
SEm (±)	0.051	0.046	-
CD@ 5%	0.205	0.184	-

Conclusion

Results indicated that the spray drying method had satisfactory capability to dry and produce malt extract powder with desired properties. However, the drying efficiency severely depended on factors including inlet air temperature and total solids in the feed. The developed spray dried grain amaranth malted milk powder with long shelf life could help in available throughout the year. increasing inlet air temperature and total solid concentration in the feed would enhance spray drying performance and malt extract powder properties. The qualitative and quantitative properties of malt extract powder were found more desirable at 150 °C. Further increase in drying air temperature increases energy consumption and has a negative effect on the malt powder quality. Shelf-life study of the spray-dried malted milk powder was carried out for 3 months in metalized polyester package. The observations were recorded for fresh product and at the end of storage period. The different parameters like moisture content, water activity, Bulk density, pH, colour values, sensory attributes and microbial load of the malted milk powder were evaluated to measure the acceptability of the fresh as well as stored products. It was observed from the study that there was an increase in the values of all the above parameters with the duration of storage. However, the malted milk powder remains acceptable more than 3 months. The shelf-life of spray dried powder will be more than 12 months. Besides, it was observed that metalized polyester packaging was better than other packaging materials for keeping malted milk powder.

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