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Effect of foaming agents on foaming properties, drying time and powder yield of rainy season *Psidium guajava* fruits cv. Shweta

Chahat Thakur, Anil Kumar Verma, PC Sharma, Manisha Kaushal, Devina Vaidya, RC Sharma and Shivani

Abstract
The study was carried out for utilization of rainy season guava fruits cv. Shweta for preparation of foam mat dried guava fruit powder. The conversion of guava fruit pulp into foam was optimized by whipping the pulp after addition of glycerol monostearate (GMS) and drying the resultant foam in dehydrator (60±5 °C) to constant moisture content. Drying of guava fruit pulp foam by using 2% GMS results in 14.74 per cent powder yield and was found the most appropriate with respect to desired foaming properties (foam density, foam expansion and foam stability), drying time and powder yield. With the increase in the foaming agent concentration, the foam density decreases significantly however, the percentage of foam expansion was increased. In comparison to foam density, the guava fruit pulp exhibited higher foam expansion of 19.42 per cent with 2% GMS whereas, (control) without foaming agents exhibited maximum foam density. Thus, the guava fruit pulp can be utilized for preparation of self-stable powder using foam mat drying technique for further preparation of value-added products.

Keywords: Guava fruit powder, foam mat, peeled without seeds, unpeeled without seeds and drying

Introduction
Guava (*Psidium guajava* L.) is one of the important fruit crop well growing in tropical and sub-tropical areas of the world and also known as 'poor man's fruit' or 'apple of tropics' (Nakasone and Paull 1998) [23]. Guava has originated in the tropical America spreading from Mexico to Peru. Portuguese introduced guava in India during 17^{th} century (Menzel, 1985) [22]. Guava ranks 5^{th} in area (2, 65,000 hectares) after Mango, Citrus, Banana and Apple comprising near about 4.07% of area under the fruit crops in India and occupies an important place in the horticultural wealth in India. Guava ranks 5^{th} with a production of 40, 54,000 metric tonnes constituting approximately 4.16% of the total fruit production in India (Anonymous, 2018) [3]. The leading guava producing states are Uttar Pradesh, Madhya Pradesh, Maharashtra and Bihar. Uttar Pradesh ranks first in area and production of guava. In Himachal Pradesh, guava covers an area of 2,292 hectares with production of 2,607 metric tonnes comprising about 0.99% and 0.46% of area and production, respectively of the total fruit crops grown in the state (Anonymous, 2018) [3]. Guava Fruits are composed of three distinct parts *viz.* peel, flesh and seed core (Wilson, 1980). Fresh guava is highly perishable due to the presence of 83 per cent moisture content and after harvest it leads to decrease in firmness and quality deterioration (Basseto *et al.*, 2005) [4].

Guava contains low protein content (1%) and energy 66 kcal/100g. Guava fruits are rich in Carbohydrates (about 60% sugars) with a predominance of fructose (59%) followed by 35% glucose and 5% sucrose (Yusof, 2003) [36], Omega-3 and Omega-6 poly unsaturated fatty acids and high levels of dietary fibre (Chin and Yong, 1980) [8], vitamins like retinol, thiamine, riboflavin, niacin, pantothenic acid, as well as minerals like phosphorous (23-37mg/100g), calcium (14-3mg/100 g), iron (0.6-1.4mg/100g) etc. It is also an excellent source of beta carotene, lycopene, potassium and soluble fiber. Guava possesses antiseptic, astringent and anthelmintic properties, useful to cure many diseases and ailments.

Among fruits, maximum post-harvest losses in guava fruits have been estimated at 15.88 per cent comprising with 11.90% in farm operations and 3.98% in different storage channels. (Jha *et al.*, 2015) [16]. Thus, there is a need to process guava into different process guava fruits into different processed products.

Drying is a process widely used in the industry to preserve the quality of agricultural products. Among the drying processes, in recent years, Foam-mat drying technology has drawn attention for its added ability to process hard-to-dry materials to produce products of desired properties, retaining its volatiles that otherwise would be lost during drying of non-foamed materials (Kudra, and Ratti, 2006) [19]. Rate of drying in this process is comparatively very high because of an enormous increase in the liquid-gas interface, in spite of the fact that the heat transfer is impeded by a large volume of gas present in the foamed mass (Martin *et al*., 1992) [21]. This method is suitable for any heat sensitive, sticky and viscous materials which cannot be dried by spray drying (Falade *et al*., 2003) [10]. The foam-mat dried products have better reconstitution properties and are superior to drum and spray dried products (Chandak *et al*., 1974) [6]. The advantages of this method include lower temperatures and shorter drying times, because of the increase in the surface area in contact with the air, which increases the water removal speed, in addition, it also maintains the highly nutritional value of per gram powder and sensory quality of the product (Kadam *et al*., 2010) [17].

Material and Methods

Selection of fruits and foaming agents

Fresh and uniformly matured fruits of Shweta cultivar of guava were procured from the orchard of the college of Horticulture and Forestry Neri and Bhota experimental farms of the college for use in experimentation for the preparation of foam mat dried guava fruit powder. For extraction of fruit pulp fruits were cut into small pieces with stainless-steel knife, one set of fruits was peeled and seeds were removed, while another set was used as without peel with seeds. The small pieces of guava fruits with and without peel and seed were mixed with little quantity of water followed by boiling till softening. The boiled pulp was passed through the pulper to extract fine pulp. The pulp was heated to 90˚C, cooled and to which KMS (500ppm SO_2) and packed in pre-sterilized glass bottles. Guava fruit powder was prepared by converting the pulp to a stable foam after using appropriate concentration of foaming agents such as Carboxymethyl cellulose (CMC) or Glycerol monostearate (GMS). The prepared foam from the guava fruit pulp was spread on suitable stainless-steel trays with a tray load rate of 100g/tray in a thin layer (3-5mm) and dried in a mechanical dehydrator at 60±5℃ to a moisture content of about 5%. After drying, the dried material was scrapped from the trays and further ground to a fine powder.

Foaming Properties

The efficiency of foaming agent to convert the guava fruit pulp into a stable foam was optimized by evaluating various foaming properties as under:

Foam density

The density of the foamed guava pulp was calculated as ratio of mass of foam to the volume of foam and expressed as g/cm^3 (Falade *et al*., 2003) [19]. The density of Guava pulp was determined by weighing 100 ml of the pulp in a 100 ml measuring cylinder whereas for the foamed guava pulp, 200 ml of foam was transferred into a 250 ml measuring cylinder and weighed. The foam transferring was carried out carefully to avoid destroying the foam structure or trapping the air voids while filling the cylinder. The foam density was calculated using the following formula:

$$\text{Foam Density } (g/cm^3) = \frac{\text{mass of the foam (g)}}{\text{volume of the foam (cm}^3\text{)}}$$

Foam expansion

It is the percentage increase of the volume of the pulp after foaming with required amount of the foaming agent and whipping time. The foam quality of foamed guava pulp in terms of foam expansion was calculated according to the following equation (Akiokato *et al.*, 1983) [2].

$$\text{Foam expansion (\%)} = \frac{V_1 - V_0}{V_0} \times 100$$

Where,
V_0= initial volume of the guava pulp before foaming (cm^3),
V_1= final volume of the guava pulp after foaming (cm^3).

Foam stability

50 ml of foamed guava pulp was placed in a 50 ml glass tube and kept undisturbed at normal atmosphere for 2 hours (Marinova *et al*., 2009) [20]. Then the decrease of the foam volume was noted after every 30-minute time interval. The reduction of the foam volume was noted to be used as an index for the determination of the stability after every 30 minutes by using following formula:

$$\text{Foam stability (\%)} = \frac{V_0}{V_1} \times 100$$

Where
V_0= initial volume of the guava pulp before foaming (cm^3),
V_1= final volume of the guava pulp after foaming (cm^3).

Powder Yield (%)

After drying of foam in the mechanical dehydrator, dried material was scrapped from the trays and weighed to find out the powder recovery as follows,

$$\text{Powder Yield (\%)} = \frac{\text{weight of powder (g)}}{\text{weight of fruit pulp (g)}} \times 100$$

Statistical analysis

Data on fruit, fruit pulp and instant powder were analyzed statistically by following completely randomized design (CRD) of Cochran and Cox (1967) [9].

Results and Discussion

Foam density (g/cm^3)

A perusal of data in Table 1 shows that the foam density among two types (unpeeled with seeds and peeled without seeds) of guava fruit pulp varied from 0.80 to 0.97 g/cm^3 obtained from Shweta cultivar of guava evaluated with 0-2 per cent concentrations each of CMC and GMS. With the increase in concentrations of foaming agents in guava pulp, foam density values register a decreased from 0.96 g/cm^3 in control to 0.81 g/cm^3 with 2 per cent GMS. The foam density was found to be higher in pulp obtained from unpeeled with seeds fruits of guava (0.89 g/cm^3) as compared to pulp extracted from peeled without seeds fruits (0.88 g/cm^3). Among foaming agents, higher foam density was found with CMC (0.91 g/cm^3) as compared to GMS (0.87 g/cm^3). However, the interaction between the pulp types, foaming agents and concentration were found to be non-significant. The foam density exhibited the decreasing trend with increased concentration of each foaming agents (Figure 1).

Similar decreasing trend of foam density with increase in foaming agents concentration has been reported by Rani *et al.* (2020) [27] in different cultivars of mango, Shivani *et al.* (2019) [30] in papaya; and Rajkumar and Kailappan (2006) [26] in *Totapuri* cultivar of mango. Affandi *et al.* (2017) [1] reported that the reduction in foam density with increasing concentration of foaming agents was probably due to the reduction in the interfacial tension and surface tension of the pulp which form an interfacial film.

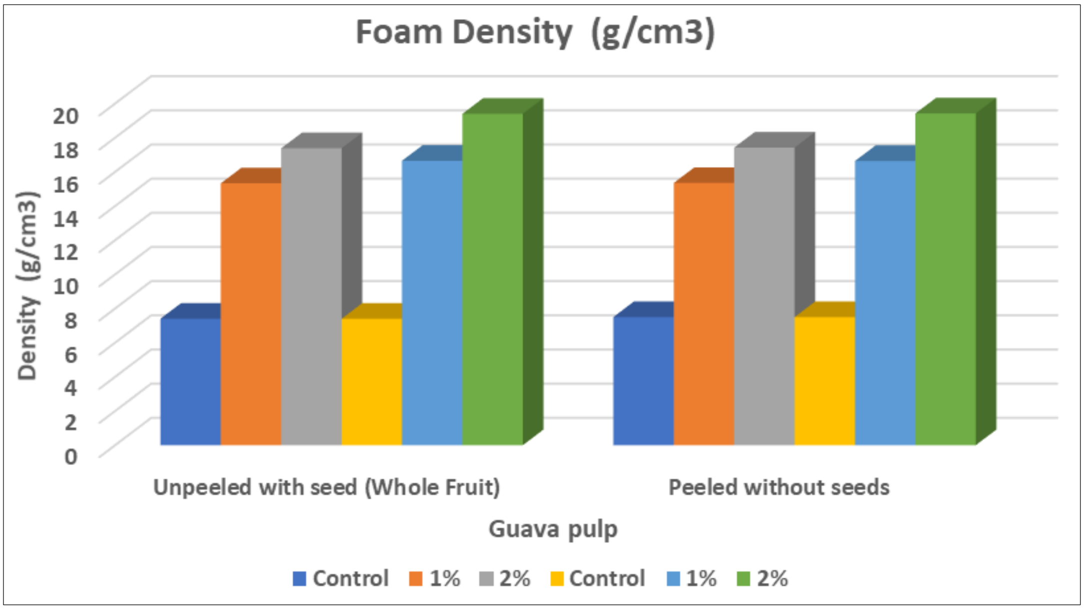

Fig 1: Effect of foaming agents on foam density of guava fruits pulp

Table 1: Effect of foaming agents on foam density (g/cm^3) of guava fruits pulp

Foaming agents (F)	Concentration (C) (%)	Foam density (g/cm^3) Pulp: Unpeeled with seed (Whole Fruit)	Peeled without seeds	Mean	Grand Mean (C)
CMC	Control	0.97	0.96	0.96	0.96
	1.0	0.90	0.89	0.89	0.87
	2.0	0.88	0.87	0.87	0.84
	Mean	0.92	0.90	0.91	
GMS	Control	0.97	0.96	0.96	
	1.0	0.85	0.84	0.84	
	2.0	0.81	0.80	0.81	
	Mean	0.87	0.86	0.87	
	Grand Mean (U&P)	0.89	0.88		
CD00.5					
Pulp (P)		0.005			
Foaming agent (F)		0.005			
P X F		NS			
Concentration (C)		0.006			
P X C		NS			
F X C		0.008			
P X F X C		NS			

Where
CMC = Carboxy-methyl-cellulose
GMS = Glycerol-mono-stearate

Foam expansion (%)
The effect of different foaming agents on foam expansion of fruit pulp obtained from unpeeled with seeds and peeled without seeds fruits of Shweta cultivar of guava is presented Table 2. The level of foam expansion in guava fruits cv. Shweta pulp evaluated by using different concentration of foaming agents ranged between 7.40 to 19.42 per cent. The fruit pulp foamed without foaming agents (control) exhibited the lowest foam expansion level (7.45%) while, pulp foamed with 2 per cent GMS showed highest level of foam expansion (19.41%). Treating fruit pulp with increasing concentration of foaming agents brought significant increase in foam expansion level. The higher foam expansion (13.97%) was observed in case of peeled fruits without seeds pulp as compared to unpeeled with seeds pulp (13.39%). Among foaming agents, higher foam expansion level was found in GMS (13.97**%**) as compared to CMC (13.93%). However, the interaction between the pulp types, foaming agents and concentration were found to be non-significant. Higher foam expansion specifies that more air was trapped in the foam because foaming agent reduces the surface tension and interfacial tension to a level sufficiently low to form the interfacial film. The foam expansion exhibited the increasing trend with increased concentration of CMC and GMS foaming agents (Figure 2).

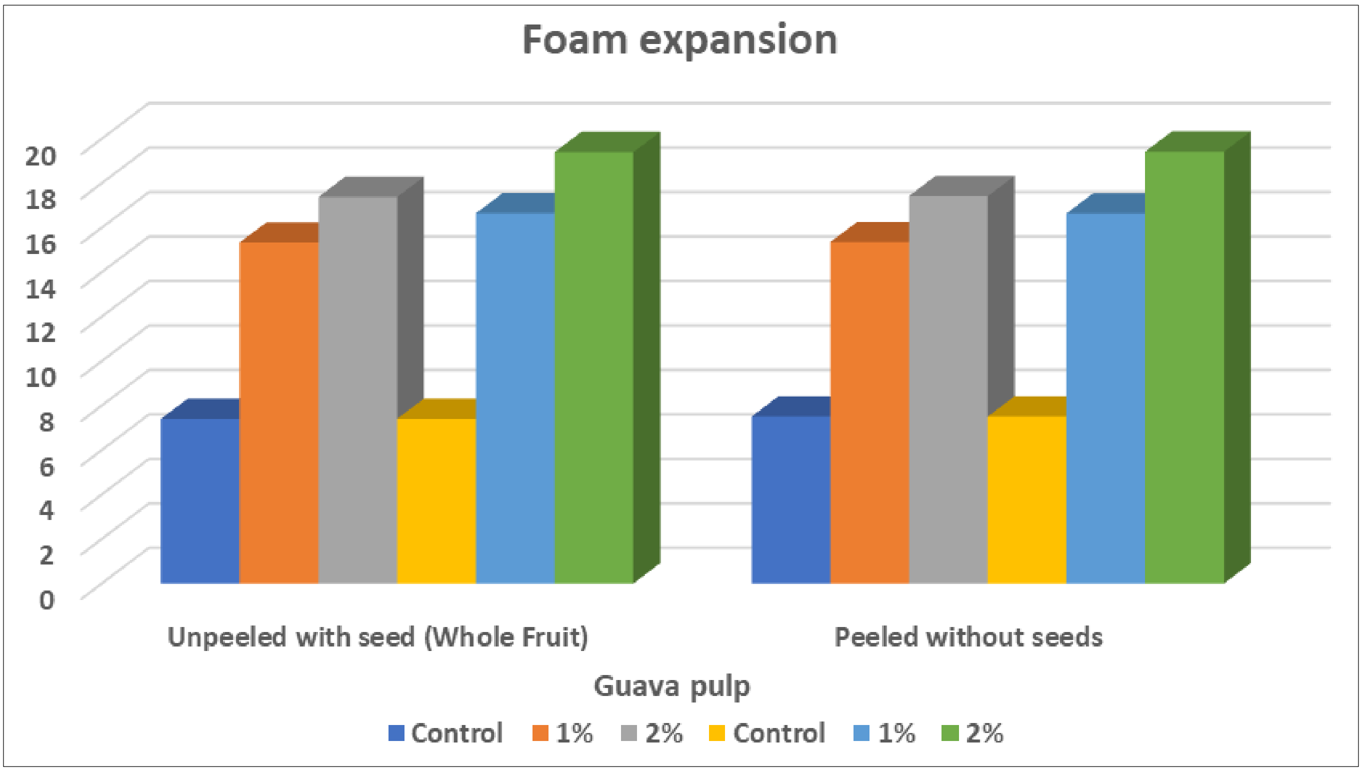

Fig 2: Effect of foaming agents on foam expansion of guava pulp foam

Table 2: Effect of foaming agents on foam expansion of guava fruits pulp

Foaming agents (F)	Concentration (C) (%)	Foam expansion			
		Pulp		Mean	Grand Mean (C)
		Unpeeled with seed (Whole Fruit)	Peeled without seeds		
CMC	Control	7.40	7.50	7.45	7.45
	1.0	15.33	15.35	15.34	15.99
	2.0	17.38	17.42	17.40	18.41
	Mean	13.37	13.42	13.93	
GMS	Control	7.40	7.50	7.45	
	1.0	16.65	16.64	16.65	
	2.0	19.40	19.42	19.41	
	Mean	13.42	14.52	13.97	
	Grand Mean (U&P)	13.39	13.97		
$CD_{00.5}$					
Pulp (P)		0.021			
Foaming agent (F)		0.021			
P X F		NS			
Concentration (C)		0.026			
P X C		0.036			
F X C		0.036			
P X F X C		NS			

Where,
CMC = Carboxy-methyl-cellulose
GMS = Glycerol-mono-stearate

Our findings are in consonance with Rani *et al.* (2020) [27] in case of foam mat dried mango fruit powder, Shivani *et al.* (2019) [30] in foam mat dried papaya fruit powder and Rajkumar and Kailappan (2006) [26] in mango powder.

Foam stability

The foam stability of fruit pulp obtained from unpeeled with seeds and peeled without seeds fruits of guava cultivar Shweta evaluated by using different concentrations of CMC and GMS ranged from 0 to 100 per cent (Table 3). The fruit pulp foamed without foaming agents (control) exhibited the no foam stability level (0.00%) while, pulp foamed with 2 per cent GMS showed highest level of foam expansion (99.53%). Treating fruit pulp with increasing concentration of foaming agents brought significant increase in foam stability level. The higher foam stability (65.74%) was observed in case of peeled fruits without seeds pulp as compared to unpeeled with seeds pulp (64.56%). Among foaming agents, higher foam stability level was found in GMS (65.82**%**) as compared to CMC (65.49%). However, the interaction between the pulp types, foaming agents and concentration were found to be significant. The foam stability exhibited the increasing trend with increased concentration of CMC and GMS foaming agents (Figure 3).

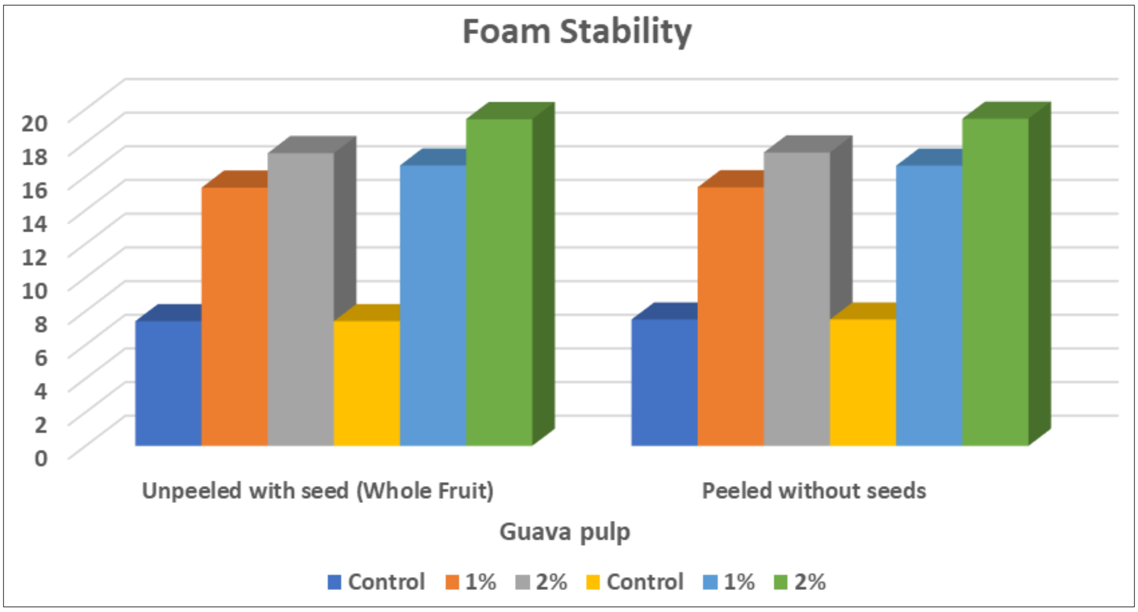

Fig 3: Effect of foaming agents on foam stability of guava pulp foam

Table 3: Effect of foaming agents on foam stability of guava fruits pulp

Foam stability					
Foaming agents (F)	**Concentration (C) (%)**	**Pulp**		**Mean**	**Grand Mean (C)**
		Unpeeled with seed (Whole Fruit)	**Peeled without seeds**		
CMC	Control	0.00	0.00	0.00	0.00
	1.0	97.40	97.43	97.41	97.67
	2.0	99.03	99.07	99.05	99.29
	Mean	65.48	65.50	65.49	
GMS	Control	0.00	0.00	0.00	
	1.0	97.90	97.95	97.93	
	2.0	99.06	100.00	99.53	
	Mean	65.65	65.98	65.82	
	Grand Mean (U&P)	64.56	65.74		
$CD_{00.5}$					
Pulp (P)		0.014			
Foaming agent (F)		0.014			
P X F		0.019			
Concentration (C)		0.017			
P X C		0.024			
F X C		0.024			
P X F X C		0.033			

Where,
CMC = Carboxy-methyl-cellulose
GMS = Glycerol-mono-stearate

Similar increasing trend of foam stability with increasing the concentration of foaming agents has been reported by Rani *et al.* (2020) [27] in foam mat dried mango powder, Shivani *et al.* (2019) [30] in foam mat dried papaya powder, Affandi *et al.* (2017) [1] in foam mat dried Nigella sativa powder and Rajkumar and Kailappan (2006) [26] in foam mat dried mango powder.

Effect of foaming agents on drying time of guava pulp

The guava pulp after converting into foam by using different foaming agents was dried in a cabinet drier at 60±5°C. The drying time in two types (unpeeled with seeds and peeled without seeds) of guava fruit pulp of cultivar Shweta from 7.41 to 9.21 hours, evaluated by using different concentrations of CMC and GMS (Table 4). With increasing the concentration of foaming agents, the mean drying time was found to be decreased from 9.19 hours (control) to 7.48 hours (2% GMS). The more drying time (8.41 hours) was observed in unpeeled with seeds fruits powder as compared to peeled without seeds powder (8.35 hours). Among foaming agents, more drying time was recorded in treated with CMC (8.50 hours) as compared to GMS (8.26 hours). However, the interaction between the pulp types, foaming agents and concentration were found to be significant. A reduction in drying time of guava pulp obtained from cultivar Shweta with increasing the concentration of foaming agents was observed (Figure 4). The reduction in drying time with increase in concentration of foaming agents could be due to the porous nature of the foamed sample allowing faster movement of dry air (Gupta and Alam, 2014) [13]. Similar results reduction in drying time with increase in concentration of foaming agents has been reported by Rani *et al.* (2020) [26] in foam mat dried mango powder, Shivani *et al.* (2019) [30] in foam mat dried papaya powder, Kandasamy *et al.* (2014) [18] in foam mat dried papaya powder, Wilson *et al.* (2012) [33] in foam mat dried mango powder and Sharma *et al.* (2002) [28] in hill lemon juice powder.

Table 4: Effect of foaming agents on drying time of guava fruits pulp

Foaming agents (F)	Concentration (C) (%)	Drying Time: Pulp: Unpeeled with seed (Whole Fruit)	Drying Time: Pulp: Peeled without seeds	Mean	Grand Mean (C)
CMC	Control	9.21	9.18	9.19	9.19
	1.0	8.26	8.24	8.25	8.18
	2.0	8.06	8.02	8.04	7.76
	Mean	8.51	8.48	8.50	
GMS	Control	9.21	9.18	9.19	
	1.0	8.16	8.05	8.11	
	2.0	7.55	7.41	7.48	
	Mean	8.31	8.21	8.26	
	Grand Mean (U&P)	8.41	8.35		
CD00.5					
Pulp (P)		0.012			
Foaming agent (F)		0.012			
P X F		0.017			
Concentration (C)		0.015			
P X C		0.021			
F X C		0.021			
P X F X C		0.030			

Where
CMC = Carboxy-methyl-cellulose
GMS = Glycerol-mono-stearate

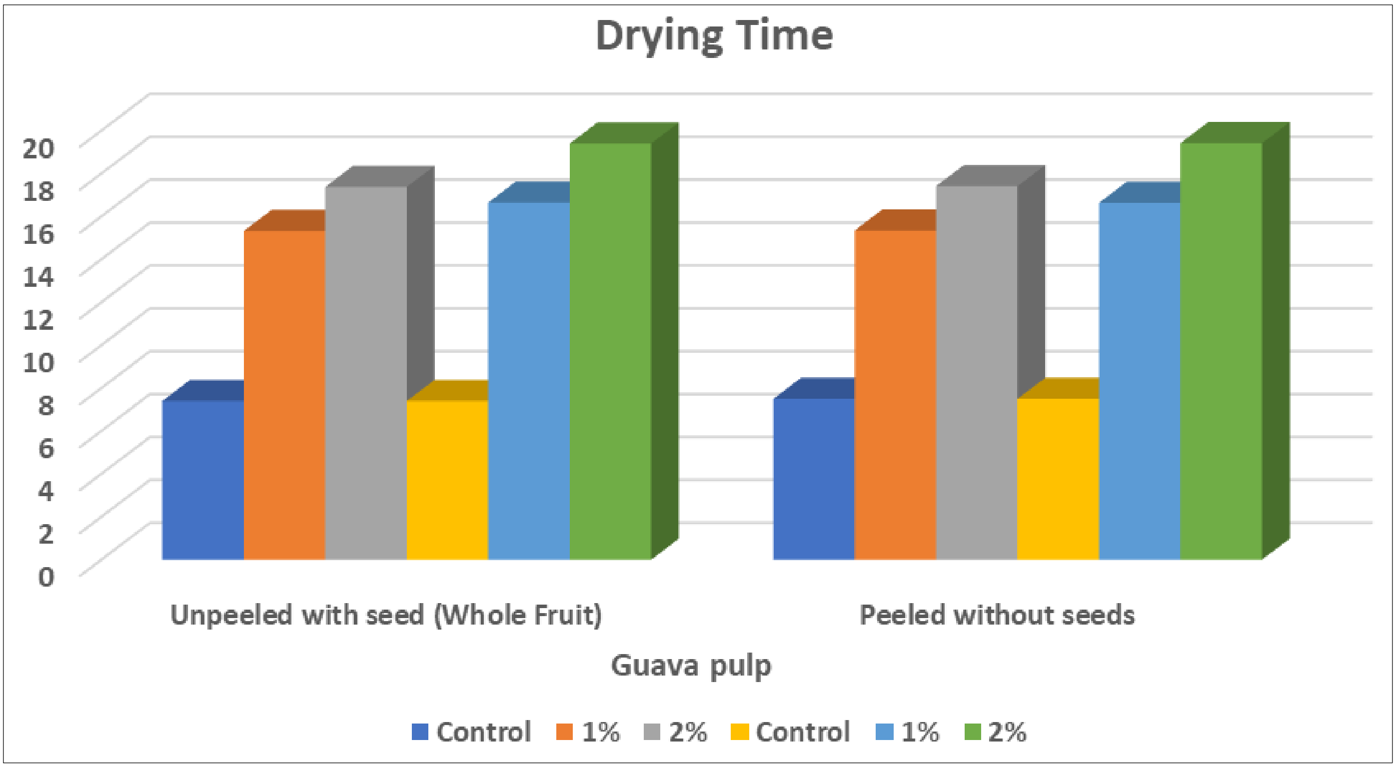

Fig 4: Effect of foaming agents on drying time of guava pulp foam

Effect of foaming agents on powder yield (%) of foam mat dried guava fruit pulp

The yield of dried guava powder obtained from unpeeled with seeds and peeled without seeds of cultivar Shweta evaluated by using different concentrations of CMC and GMS ranged from 13.83 to 14.74 per cent (Table 5). The mean powder yield was found to be increased with increasing concentration of foaming agents from 13.84 (control) to 14.72 per cent (2% GMS). The highest powder yield (14.20%) was observed in unpeeled with seeds fruits powder as compared to peeled without seeds powder (14.18%). Among foaming agents, higher powder yield was observed in GMS 14.37 per cent against 14.01 per cent in CMC. However, the interaction between the cultivars, pulp types and foaming agents were found to be non-significant. Treating pulp with increased concentration of foaming agents brought about significant increased powder yield (Figure 5).

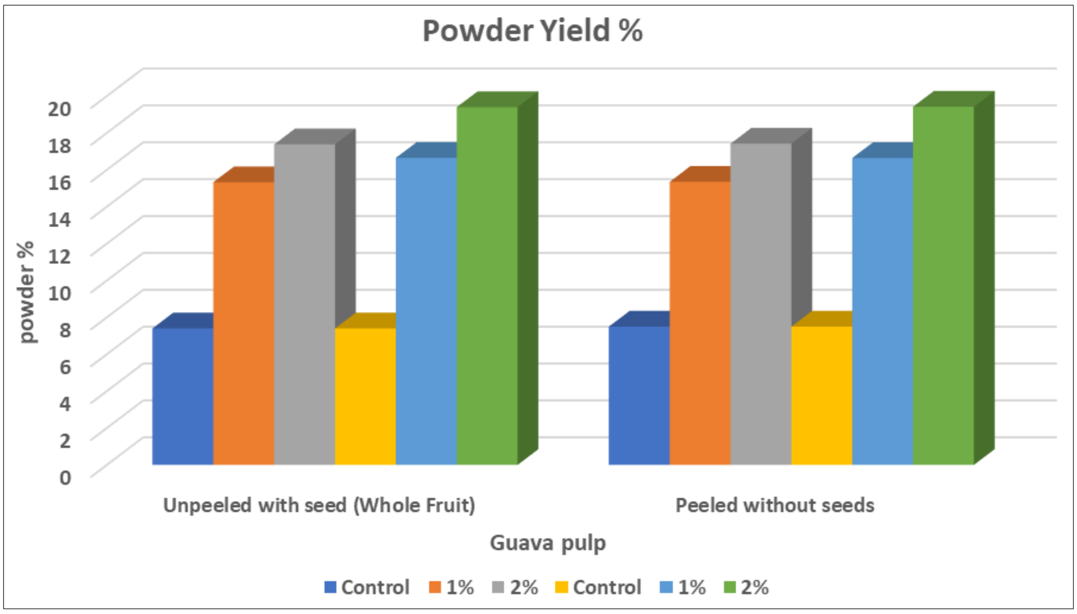

Fig 5: Effect of foaming Agents powder yield of guava fruit pulp foam

Table 5: Effect of foaming agents on powder yield of guava fruits pulp

Powder Yield (%)					
Foaming agents (F)	**Concentration (C) (%)**	**Pulp**		**Mean**	**Grand Mean (C)**
		Unpeeled with seed (Whole Fruit)	**Peeled without seeds**		
CMC	Control	13.85	13.83	13.84	13.84
	1.0	14.05	14.03	14.04	14.28
	2.0	14.15	14.14	14.14	14.43
	Mean	14.02	14.00	14.01	
GMS	Control	13.85	13.83	13.84	
	1.0	14.54	14.52	14.53	
	2.0	14.74	14.71	14.72	
	Mean	14.38	14.35	14.37	
	Grand Mean (U&P)	14.20	14.18		
$CD_{0\,0.5}$					
Pulp (P)		NS			
Foaming agent (F)		0.046			
P X F		NS			
Concentration (C)		0.057			
P X C		NS			
F X C		0.081			
P X F X C		NS			

Where,
CMC = Carboxy-methyl-cellulose
GMS = Glycerol-mono-stearate

Similar increasing trend in powder yield with increase in the concentration of foaming agents were reported by Rani *et al.* (2020) [26] in different cultivar of mango varied from (13.72 to 15.10%). Shivani *et al.* (2019) [30] in *Madhu* cultivar of papaya (10.10 to 11.93%). Sharma *et al.* (2002) [28] has also reported increase in foam mat dried hill lemon juice powder (8.03 to 11.18%).

Conclusion

From the above study, it is concluded that foam mat drying of peeled without seeds pulp is indeed a better substitute for preservation of guava fruit in the form of dried powder. Guava, being a highly perishable crop due to high moisture content, is very prone to microbial infestation during a growing period that results in a lot of mess in its storage and transportation and fetches low prices to growers during glut season. The present study indicates that with such processing of guava fruit pulp could be conserved in the powdered form for a long period of time by use of 2 per cent GMS. So, foam mat drying, which is a good alternative to other drying processes, is a promising potential for the food and fruit processing industry.

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