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Solar Dried Natural Ingredients based Antioxidant Rich Nutritional Supplements for Service Personnel stationed at High Altitudes - Product Development, Nutritional Evaluation and Storage Studies

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Abstract: Service personnel deployed in Himalayan regions at higher altitude are often distraught both psychologically and physically due to the ubiquitous environmental conditions, strenuous field activities and the associated metabolic alterations in their nutrient and energy requirements. Hypobaric hypoxia, physical exercise and heightened metabolic rate causes oxidative/ reductive stress due to activation of reactive oxygen and nitrogen species [RONS] generating systems causing oxidative damage to lipids, proteins, and DNA. The antioxidants produced *insitu* fall short of the natural buffering capacity. Potential antioxidant vitamins – A, E, and C particularly from natural sources have been found to control the negative influence of free radicals and allied disruptive reactions. Hence, an attempt has been made herein to design, formulate and develop ready-to-eat type of Antioxidant Rich Nutrient [ARN] Bars using cereals, pulses, fruits and vegetables etc., which are known to be rich in vitamin–C, β- carotene, vitamin E, iron and selenium. Fruits and vegetables processed with ***Green Energy*** have been used herein due to their better micro nutrient density and longer storage stability. The ARN bars developed in the ready-to-eat compacted form and packaged in metalized polyester (12μ) LD/ LLD (MP, 75 μ) pouches have been found to be shelf stable for nearly four months, with no adverse effect on their safety of consumption, organoleptic quality and antioxidant potency. These ARN bars when used by the

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Service Personnel as a snack food are expected to meet their additional antioxidants demand.

Keywords: Service Personnel, High Altitudes, Antioxidant Capacity, Green Energy, Solar Drier, Fruits and Vegetables.

1. Introduction

Service personnel deployed at high altitudes of the Himalayas, are exposed to the all-pervading environmental stress and this coupled with strenuous military activities renders them overwrought both physically and psychologically, despite the acclimatization measures adopted (Lovilin *et al.*, 1987; Selvamurthy and Singh, 2003; McArdle *et al.,* 2010). Hypobaric hypoxia and deepened metabolic rate at high altitudes together with the associated enhanced generation of reactive oxygen and nitrogen species [RONS] due to activation of RONS generating systems, including the electron transport chain, xanthine oxidase, and nitric oxide synthase,could cause oxidative/ reductive stress leading to oxidative damage of lipids, proteins, and DNA (Moller *et al.,* 2001; Tibor Bakonyi and Zsolt Radak , 2004; Vollaard *et al.,* 2005; Knez *et al*., 2006 ; Dosek *et al.,* 2007; König *et al.,* 2007; Fisher-Wellman and Bloomer, 2009; Patil *et al*., 2012; O'keefe *et al*., 2012). Physical exercise at high altitude exacerbates the degree of oxidative challenge (Dosek *et al.,* 2007; Sinha *et al.,* 2009). Chronic exposure to both cold and hypoxia in moderate climatic situations could cause greater oxidative stress due to altered metabolic rate (Pfeiffer *et al*., 1999).

Under normal conditions the physiological system has the inherent ability to generate antioxidants like glutathione, catalase and superoxide dismutase to protect healthy cells from related damage (Schmidt *et al.,* 2002). Even vitamin E β-carotene, and coenzyme Q10, found in the fat-soluble cellular membranes have been found to act as potential antioxidants in controlling the negative influence of free radicals and related disruptive reactions (Vollaard *et al.,* 2005; Knez *et al.,* 2006; Fisher-Wellman and Bloomer, 2009; O'keefe *et al*., 2012). Vitamin E is considered as the most potent chain breaking antioxidant within the membrane of the cell (Moller *et al*., 2001) while β-carotene is the most efficient "quencher" of singlet oxygen (König *et al.,* 2007). Sincehypobaric hypoxia coupled with heavy and sustained exercise produces large quantities of free radicals compared to during moderate exercise, the *in situ* antioxidants potential fall short of the buffering capacity, inducing the body susceptible to oxidative stress affecting noticeably the overall health (Fisher-Wellman and Bloomer., 2009; Patil *et al*., 2012). Supplementation of diets with potential antioxidants like vitamin A, C and E have been found to have several desirable effects like prevention of weakening of blood flow, mitigation of the negative effect arising as a result of free radical damage to cellular antioxidant defence systems,on physical performance etc. (Sumida *et al.,* 1989; Simon-Schnass., (1996); Pfeiffer *et al.,* 1999; Schmidt *et al.,* 2002; Dosek *et al.,* 2007). Inclusion of a wide variety of plant based foods together with fruits and vegetables in the diets of people engaged in strenuous physical activity has been found to assuage the oxidative stress related disturbances, by maintaining optimal antioxidant status (Deepak *et al.,* 2015). In view of this supplementation of the regular diets of Armed Forces at high altitude regions with naturally available antioxidants is necessitated. An attempt has been made herein to design and formulate nutrient supplements in the form of a snack bar, using various food items such as cereals, pulses, solar dried fruits and vegetables etc. which are known to be rich in vitamin–C, β-carotene, vitamin E, iron and selenium, which when consumed could effectively combat the oxidative stress in Service Personnel stationed at High Altitudes.

2. Materials and Methods

2.1. Processing of Ingredients vis-a-vis Antioxidant Rich Nutrient Bars

Two types of Antioxidant Rich Nutrient (ARN) bars have been planned with the only variant being use of either Ragi (*Eleusine Coracana*) or Moong (*Phaseolus aureus Roxb*). The quantities / proportion of the various ingredients employed in the development of both ragi and moong based ARN Bars were arrived after several preliminary trials using the constituents in numerous permutations and combinations, keeping in view the sensory attributes, microbiological safety, antioxidant status etc., The various ingredients and their proportion finally used in the dried powdered form include: Sugar (*Saccharum officinarum)* 32%; Guar Gum (*Cyamopsis tetragonoloba*) 0.5 %; Spinach (*Spinacia Oleracea*) 5.0 %; Amaranthus (Amaranth –*Amaranthus viridis*) 5.0 %; Wheat grass (*Triticum aestivum)* 2.0 %; Drumstick leaves (*Moringa oleifera*) 5.0 %; Carrot (*Daucus Carota L*) 8.0 %; Tomato (*Lycopersicon Esculentum*) 17 %; Almonds (*Prunus amygdalus*) 5.0%; White Sesame Seeds (*Sesamum indicum*) 5.0%; Ginger *(Zingiber officinale)* 1.0 %; Amla (*Emblica officinalis*) 1.0 %; Defatted Soy Flour (*Glycine max Merr.)* 8.0 %; Ragi (*Eleusine Coracana*) Malt or Sprouted Green Gram (*Phaseolus aureus Roxb*) Malt 5.5 %.

All the raw materials of superior quality were procured locally and processed as described below. Drying of the materials was accomplished using a Solar Cabinet Dryer fabricated at SEED and patented (Fig. 1). Guar Gum powder, Ginger powder and Defatted Soy Flour were however used as procured while Sugar was powdered herein.

2.1.1. Processing of Drumstick Leaves, Spinach, Amaranthus, Wheat Grass, Carrot, Tomato and Amla

Spinach, Amaranthus, Wheat grass, Drumstick leaves, scraped Carrot, Tomato and Amla were thoroughly washed in 0.2 % chlorinated water. Spinach, Amaranthus and Wheat grass were blanched individually in 0.2 % sodium bi carbonate ($NaHCO_3$) solution at 90°C for 2′. The drumstick leaves were blanched with 0.2% magnesium oxide [MgO] solution instead of $NaHCO_3$. On the other hand, carrot and tomato were blanched in boiling water for one minute. Amla was also blanched in boiling water but for ten minutes to facilitate the product to be soft enough to enable removal of the embedded seed with ease. The blanched carrots and tomatoes were sliced while amla was deseeded and cut into small bits to facilitate drying. The various materials were individually and evenly spread in thin layers [2 - 5 kg/M^2] on the SS trays of the Solar Cabinet Dryer (Fig. 1) and dried at a temperature ranging between 40^0– 60^0C to a final moisture content of 4-6 %. The drying time and the yield depended on the initial moisture content.The dried products were cooled to room temperature, pulverized (70 mesh),packaged in metallized polyester (12μ LD/ LLD - MP 75 μ) pouches of appropriate size & stored in a cool & dry place.

2.1.2. Processing of Ragi and Green Gram

Ragi and Green Gram Thoroughly cleaned and washed was soaked for 6 hrs separately in warm water,excess water was drained off and allowed to sprout for 36 hrs in a sprouter. The sprouted material was individually dried as above and then roasted at 70°C.Sprouts were separated and powdered in a pulverizer, packaged and stored as above.

2.1.3. Processing of Almonds and White Sesame seeds

Almonds manually made into small bits were roasted to light brown color in an open pan ≈ 90°C. In order to avoid formation of lumps while powdering the cooled almond bits were mixed with a portion(in the ratio 1:1) of the calculated quantity of sugar, as per the formula and powdered in a domestic mixer. Likewise sesame seeds were also processed.

2.1.4. Processing of Antioxidant Rich Nutrient [ARN] Bar

Initially two types of ARN bars - Ragi and Moong based -were processed, with and without chocolate coating, as described hereunder.

Flow Chart: Antioxidant Rich Nutrient [ARN] Bar with & without Chocolate coating:

Solar Dried and Powdered Ingredients; taken in Standardized Quantities.

Kneaded into dough with RO water; not exceeding 40% of the dry wt.

Moulded in the shape of a *Chocolate Bar*[30g]*, using a Stainless SteelMould

The Bars were then Solar dried for ≈ 8 hrs at 60°C.

50 % of the bars werecoated with liquid chocolate [(Melt 70% Dark Chocolate Compounds+ 30% Milk Compounds) in a microwave oven for 5'] and tempered.

**Consumption of a 30 g bar/day has been calculated to provide additional antioxidants not barring the Recommendations of professional bodies like ICMR and FAO.*

Both the types [*viz.*, Ragi and Moong based] of ARN bars, were assessed microbiologically for their safety of consumption and subjected to sensory evaluation, on a 9-point Hedonic Scale. The chocolate coated ARN bars of both the types were graded as very good compared to a satisfactory score for non-coated products. Hence the present studies were confined only to chocolate coated products.

The quantities of each of the Ragi and Moong based chocolate coated antioxidant rich nutrient (CC-ARN) bars required for storage studies as well as for basal values were prepared, packaged in metalized polyester (12μ) LD/LLD (MP, 75 μ)pouches of appropriate size and stored under ambient (Tempr. 30 -35^{o}C; humidity 54 – 71 %, prevalent in Hyderabad during the months ofJune – October), refrigeration (4-5^{0}C) and frozen(-18°C) conditions. Fresh samples required for various microbiological / nutrient / sensory evaluations were randomly separated and analysed within a short period of two to three days. Stored samples were periodically drawn and the proposed parameters were evaluated as described below.

3. Microbiological Quality

Several fresh samples of Ragi and Moong based products were evaluated for Total plate count (TPC), Yeasts and Moulds and *E. coli by* the standard procedures (APHA (1992); FAO- (1997); AOAC (1985). Similarly the stored samples drawn at the end of 30, 60 and 120 days of storage period under different conditions, were also evaluated.

4. Sensory Evaluation

Sensory Evaluation trials were conducted with fresh as well as stored samples drawn at the end of 30, 60 and 120 days from batches stored under different conditions of storage on a Nine – Point Hedonic Scale.A minimum of ten panelists from different ethnic background were utilized for the purpose.

5. Evaluation of Nutrient Composition and Antioxidant Constituents

The Proximal Score of all the ingredients used in the development of the CC- ARN bars and the finished products, fresh / stored, were evaluated by the standard AOAC methods (AOAC, 1985) as described by Ranganna (Ranganna, 1986; Pearson and Ranganna, 1995). The two types of fresh CC-ARN bars together with their stored counter parts drawn at the end of 30, 60, and 120 days of storage at different conditions were evaluated for their content of total and reducing sugars; browning index (Pearson & Ranganna, 1995) and Vitamin – C (BIS – IS: 5838 , 1970). Antioxidant components were evaluated in both the types of fresh and stored CC ARN bars by different methods described elsewhere and quoted herein; vitamin E (Hove and Hove, 1944; Desai, 1984), total carotenoids (Arya *et al* , 1979), total polyphenols, total flavonoids (Singleton and Rossi, 1965) and total antioxidant activity (Brand-Williams *et al.,* 1995). Due to some technical and inherent practical restraints, samples stored for 120 days only were evaluated.

6. Results and Discussions

6.1. Microbiological quality

The total plate count (TPC) for several fresh samples of both the types from different batches ranged between 5000 to 6000 cfu/ g against the permissible limit of 40000 cfu/ g. In the case of products stored for various periods under different conditions of storage the TPC ranged as shown below:

At ***Ambient Conditions*** (Tempr. 30 -35^{o}C; humidity 54 – 71 %, prevalent in Hyderabad during the months ofJune – October), **30 days storage;** 5736 – 6500 cfu/G; **60 days** 7000 – 7200 cfu/G; **120 days** 7000 – 7800 cfu/g;

At ***Refrigerated Conditions*** [4-5^{o} C] **30 days** 7000-7200 cfu/G; **60 days** 2000-6500 cfu/G; **120 days** 2000-6712 cfu/g;

At ***Frozen Conditions*** [-18° C] **30 days** 5000-6800 cfu/G; **60 days** 5200-6500 cfu/G; **120 days** 5000-7050 cfu/g.

Yeasts, Moulds and *E coli* were absent in all the fresh samples and those stored at various conditions and periods, indicating that the products are safe for consumption up to 120 days of storage under varied conditions.

6.2. Sensory Studies

Sensory scores of the samples CC-ARN bars both fresh and stored at varied conditions and period are given in Table– 1.As seen the sensory scores of fresh samples from various batches of ragi basedCC- ARN bars rated the overall acceptability to be 7 to 7.5 as against a score of 8 for the moong based product. The scores for other sensory attributes like colour, appearance, taste and texture ranged between 7 and 8 for ragi based product as against 8 for moong based item. Although both the products are good, the moong based product appeared to be better with respect to the sensory attributes / eating quality.

Similarly the ratings with respect to different stored products also indicated high acceptability for moong based bars compared to the ragi based product. The other scoring characteristics were also better in case of moong based item. The marginally lower score for ragi based product could be attributed to the higher fiber content and coarseness of the product. However amongst the stored products, the samples stored under frozen conditions were found to be at par with the fresh material. The samples kept at ambient conditions prevailing at Hyderabad (Tempr.30 -35°C; humidity 54 – 71 % during the months of June – October) were also acceptable despite a marginally lower score; statistically not significant [$P < 0.05$].

6.3. Nutrients Data

The Proximal score of chocolate coated ragi & moong based CC-ARN bars were found to be respectively–Moisture: 11.5 & 11.4 %; Protein: 12.4 & 13.4 %; Lipids: 6.0 & 5.9 %; Ash: 6.9 & 6.1%; Crude fiber: 9.3 & 8.7 %; Carbohydrates: 53.9 & 54.5 %; Energy: 319 & 325 Cals/100g. The variations between several values for each of the proximal constituents being negligible, the data is reported as the mean of a minimum of six values obtained with samples from different batches. The Nutrients composition of the ingredients obtained hitherto being congruent with the literature values the data has not been reported.

As seen from Table 2, the moisture, total sugars and reducing sugars content in both the types of CC-ARN bar samples does not show any marked difference consequent to storage. However a marginal increase though not significant, is seen in the total and reducing sugars content in the products stored frozen. Similarly no changes either in total fat, free fatty acid content or peroxide value were noticed. Data not reported.

6.4. Antioxidant constituents of the ingredients

The content of antioxidants like total polyphenols, total carotenoids, β-carotene,vitamin Cand vitamin E, in some of the ingredients used are reported in table 3. On extrapolation of the data with the values for the finished products, it is inferred that spinach contributed to the maximum total polyphenols (31 - 32 % of the total) followed by tomatoes (25 – 26%), and amla (20 – 21 %). The major portion of total carotenoids (94 - 97 % of the total) is derived from - Tomatoes (31 – 35 %), whilst Drumstick leaves (20 – 23 %),Amaranthus leaves (20 – 23 %), Carrot (15 – 13 %) and Spinach (12 – 14 %) followed the trail. Vitamin C was mainly derived from tomatoes followed by Amaranthus leaves and Drumstick leaves while vitamin E was from Almonds.

Table 1: Sensory Attributes of CC- ARN Bars: Fresh and stored at varied conditions of storage

Sl. No.	Traits	Zero day/ Fresh Sample	30 days			60 days			120 days		
			A*	R*	F*	A*	R*	F*	A*	R*	F*
Ragi Based CC-ARN Bar											
1	Color	8	7	8	8	7	7	8	7	7	8
2	Appearance	8	7	7	8	7	7	8	7	7	8
3	Texture	8	8	8	8	8	7	8	7	7	8
4	Taste	7	7	7	8	7	7	8	7	7	8
5	Flavor	7	7	7	8	7	7	8	7	7	8
6	OAA	7.5	7.2	7.4	8	7.5	7.0	8	7.0	7.0	8
Moong Based CC-ARN Bar											
1	Color	8	7	8	9	7	7	9	7	8	9
2	Appearance	8	8	8	9	8	7	9	7	8	9
3	Texture	8	8	8	9	8	7	9	9	9	9
4	Taste	8	7	7	9	7	8	9	7	7	9
5	Flavor	8	7	8	9	7	7	9	7	7	9
6	OAA	8	7.5	8	9	7.5	7.5	9	7.4	7.8	9

A*=Ambient 30 -35°C, R*=Refrigeration 4 – 5 ° C, F*=Frozen Condition -18° C; OAA =Overall Acceptability

Table 2: Changes in Moisture, Total and Reducing Sugars content of both the types of CC- ARN Bars stored under different conditions / periods.

(Values are mean of minimum six samples)

Storage Period [Days]	*Ragi Based*			*Moong Based*		
	Ambient	*Refrigerated 4 - 5° C*	*Frozen -18° C*	*Ambient**	*Refrigerated 4 - 5° C*	*Frozen -18° C*
Moisture %						
Zero	6.9	-	-	7.3	-	-
30	7.0	6.5	6.9	8.2	7.8	7.5
45	7.1	6.2	5.3	8.2	7.8	7.4
60	7.3	5.7	4.6	8.5	8.0	7.5
120	7.9	7.0	7.1	8.5	8.0	7.5
Total Sugars (%)						
Zero	47.3	-	-	46.5	-	-
30	45.2	44.1	46.2	43.8	45.2	45.9
45	43.2	43.9	45.9	43.2	45.6	45.6
60	42.8	42.1	40.2	42.5	45.2	45.9
120	41.0	40.6	42.5	42.0	45.0	45.6
Reducing Sugars (%)						
Zero	13.9	-	-	14.6	-	-
30	12.6	12.6	13.8	13.5	13.8	13.3
45	12.2	12.5	13.5	13.2	13.5	13.3
60	12.2	12.0	13.3	12.9	13.2	13.5
120	13.2	12.9	13.7	12.5	13.6	14.0

6.5. Antioxidant constituents of both the types of CC-ARN Bars

6.5.1. Changes in Vitamin C on storage

In the present study, as expected the loss in vitamin C content of CC-ARN Bars during storage is highly perceptive with minimal changes in the other antioxidant components especially when stored either at refrigerated or frozen conditions. As seen from table 4 there is no significant difference in the initial vitamin C content between the two types of products. Vitamin C, a highly unstable nutrient with a potential antioxidant activity was found to reduce in both the products stored at different conditions / periods. At ambient conditions significant losses ($P<0.1$) in vitamin C content in both the types of products is observed. Ragi based products stored for 120 days at ambient conditions the loss was found to be 38.8

% as against 36.6 % in the moong based counterpart. The refrigerated products are ragi *vs* moong based, the losses are 25.72 % and 22.77 % while the frozen products the loss of vitamin C are 19.6 % and 14.4 % respectively. The losses in these stored products however do not differ statistically.

Table 3: Potential Antioxidant Content of some of the Ingredients used in the Formulation of CC- ARNBars.

[Values on Moisture Free Basis are Mean ± SD of Five Batches Processed on Different Days]

Solar Dried Ingredients	*Unit*	*Total Polyphenols [as GA-Eq]*	*Total Carotenoids*	*β- Carotene*	*Vitamin C*	*Vitamin E*
Spinach	mg/100g	2404.56 ± 91.85	98.58 ±15.39	26.88 ± 05.38	312.49 ± 48.61	13.31 ± 0.21
	mg/5g	120.23	4.779	1.344	15.625	666µg/5g
Amaranthus leaves	mg/100g	174.2 ± 08.71	155.81 ± 08.07	65.09 ± 13.79	635.74 ± 80.21	3.34 ± 0.38
	mg/5g	8.71	7.791	3.255	31.787	167 µg/5g
Drumstick leaves	mg/100g	122.89 ± 59.51	159.32 ± 29.48	72.11 ± 05.86	443.88 ± 68.64	1.27 ± 0.04
	mg/5g	6.145	7.966	3.606	22.194	63.5 µg/5g
Carrot	mg/100g	401.45 ± 20.78	76.14 ± 08.88	44.03 ± 03.65	50.51 ± 16.16	1.71 ± 0.08
	mg/8g	32.116	6.091	3.522	4.041	137 µg/8g
Tomato	mg/100g	574.93 ± 32.75	72.96 ± 09.97	14.18 ± 0.92	430.45 ± 27.73	4.23 ± 0.31
	mg/17g	97.738	12.403	2.411	73.177	719 µg/17g
Almonds	mg/100g	89.19 ±01.97	ND	ND	ND	27.15 ± 3.72
	mg/5g	4.461				1358 µg/5g
Sesame Seeds white	mg/100g	232.05 ± 06.20	ND	ND	ND	1.323 ± 0.178
	mg/5g	11.603				66 µg/5g
Ginger	mg/100g	1201.15 ± 43.25	1.76 ± 0.29	0.475±0.005	29.01 ± 6.52	1.71 ± 0.16
	mg/g	12.012	0.018	0.005	0.290	17 µg/g
Amla	mg/100g	7938.70 ± 29.26	ND	ND	1940.0 ± 234.08	0.924 ± 0.154
	mg/g	79.387			19.400	9 µg/g
Defatted Soy flour	mg/100g	146.02 ± 03.68	ND	ND	ND	ND
	mg/8g	11.682				
Ragi Malt	mg/100g	151.20 ± 02.46	ND	ND	ND	0.179 ± 0.011
	mg/5.5g	8.316				11 µg/5.5g
Green gram malt	mg/100g	100.72 ± 06.09	ND	ND	ND	0.366 ± 0.022
	mg/5.5g	5.541				20 µg/5.5g

ND Not Detected

Table 4: Changes in Vitamin C content of both the types of CC- ARN Bars Due to storage under different conditions / periods.**

Storage Period Days	*Vitamin-C content (mg/100g) [On As is basis]*					
	Ragi Based CC-ARN Bar			*Moong Based CC-ARN Bar*		
	*Ambient**	*Refrigerated 4 - 5°C*	*Frozen -18°C*	*Ambient*	*Refrigerated 4 - 5°C*	*Frozen -18°C*
Zero**	160.57 ± 27.13	-	-	151.62 ± 24.39	-	-
30ᶲ	149.08 ± 22.18	152.61 ± 23.88	157.54± 27.91	139.31 ± 23.45	142.68 ± 29.11	143.41 ± 26.32
45ᶲ	137.12± 28.23	148.25± 26.33	149.63± 26.98	127.80 ± 26.57	131.37 ± 22.66	136.62 ± 19.22
60ᶲ	116.95± 26.35	131.94± 21.55	138.67± 30.11	113.37 ± 25.33	124.67 ± 19.24	127.28 ± 29.11
120ᶲ	98.21± 24.87	119.26± 23.62	129.08± 28.16	96.08 ± 23.77	117.09 ± 21.18	± 26.18

* Tempr. 30 -35°C; Humidity 54 – 71%

**Values are Mean ± SD of Five Batches Processed on Different Days represent Zero Day data,

ᶲ Values are Mean ± SD of five samples from different sachets stored at the respective storage conditions

6.5.2. Other Antioxidants perse

The data presented in table 5 clearly indicates that the content of vitamin E, total polyphenols, total flavonoids, total carotenoids and total antioxidant activity is nearly similar in both the types of products with no ostensible difference between them. The content of various antioxidant constituents calculated to derive from a serving of 30 g of ragi based bar are found to be marginally lower compared to the moong based counterpart. A bar of 30 g each of ragi *vs* moong based is calculated to provide vitamin E 867 vs 879 µg, total carotenoids 11.97 vs 10.51 mg total polyphenols 113.96 vs 118.34, total flavonoids 60.37 vs 70.25 mg and total antioxidant activity 59.25 vs 61.95 mg respectively.However the observed difference in either total flavonoids or total antioxidant activity between ragi and moong based products although appear large are not significantly different.

However the content of various antioxidant constituents of ragi and moong based CC-ARN bars for fresh *visâ vis* samples stored for 120 days under varied conditions of storage (table 5) showed a marginal decline on storage for 120 days at different conditions with the values being not different statistically. The losses are highest in the products stored at ambient conditions which appear natural in view of the high atmospheric temperatures and incompatible humidity conditions prevailing during the storage months at Hyderabad.

Table 5: Effect of storage on the Antioxidant Components of both the types of CC-ARN Barsvis a vis fresh samples. (Values are on as-is-Basis)

Antioxidant Components	*Unit*	*Zero Day*	*Storage Period120 Days*		
			Ambient (30 -35°C)	*Refrigerated (4 - 5°C)*	*Frozen -18°C*
Ragi Based CC-ARN Bar					
Vitamin E	mg / 100g	2.89 ± 0.53	2.67 ± 0.58	2.82 ± 0.45	2.79 ± 0.35
	µg/30g *	867	801	846	828
Total Carotenoids	mg / 100g	39.91 ±7.21	35.48 ± 6.91	37.73 ± 7.58	38.07 ± 6.12
	mg/30g	11.97	10.64	11.32	11.42
Total Polyphenols GA eq.	mg / 100g	379.88 ± 32.09	332.32 ± 35.88	351.01 ± 33.41	360.55 ±32.58
	mg/30g	113.96	99.71	105.30	108.17
Total Flavonoids QU eq.	mg / 100g	201.22 ± 19.82	178.82 ± 22.34	195.46 ± 18.29	197.85 ± 21.35
	mg/30g	60.37	53.65	58.64	59.36
Total Antioxidant Activity Vit.C eq.	mg / 100g	197.50 ± 18.75	181.71 ± 21.58	183.36 ± 22.34	186.97 ± 19.65
	mg/30g	59.25	54.51	55.01	56.09
Moong Based CC-ARN Bar					
Vitamin E	mg / 100g	2.93 ± 0.81	2.62 ± 0.93	2.38 ± 0.88	2.79 ± 0.91
	µg/30g	879	786	714	837
Total Carotenoids	mg / 100g	34.99 ±7.27	28.89 ± 6.52	30.17 ± 8.34	30.88 ± 7.88
	mg/30g	10.51	8.67	9.05	9.26
Total Polyphenols GA eq.	mg / 100g	394.45 ± 29.32	344.88 ± 24.66	358.32 ± 20.65	371.44 ± 21.96
	mg/30g	118.34	103.46	107.51	111.43
Total Flavonoids QU eq.	mg / 100g	234.15 ± 22.85	221.88 ± 23.91	228.74 ± 21.48	230.39 ± 24.01
	mg/30g	70.25	66.56	68.62	69.12
Total Antioxidant Activity Vit.C eq.	mg / 100g	206.50 ± 21.32	185.74 ± 19.12	192.76 ± 20.01	± 18.97
	mg/30g	61.95	55.72	57.83	58.79

30 g is the quantity of the bar per serving - packaged accordingly

Likening changes at ambient conditions of storage between ragi *vs* moong based CC-ARN bars the losses in vitamin E content is 7.6 & 10.6 %; total carotenoids 11.1 and 17.4 %; total polyphenols 12.5 and 12.6 %; total flavonoids 11.1 and 5.2 %; total antioxidant activity 8.0 and 10.1%, which can be ignored taking into consideration the natural harsh climatic conditions of storage. On the other hand the losses in these various constituents are very low in products stored at either refrigerated or frozen conditions.

The losses perceived in various antioxidant components at different conditions of storage are not statistically significant. Similar changes with respect to vitamins C, vitamin E, total phenols, carotenoids and anthocyanin have been reported (Meenakshi *et al.,* 2013) in spray dried sea buckthorn fruit juice powder packaged in metallized polyester pouches under different modified atmospheric packaging conditions, viz. air, carbon-di-oxide, nitrogen, vacuum, and stored at room temperature for a period of six months.Further the authors have also reported a significant increase in the moisture content, pH, total sugars, reducing sugars and browning. The solar dried CC-ARN Bars hitherto developed using solar dried ingredients does not reflect any such changes in the said parameters.

In view of this the CC-ARN bars can safely be considered for introduction as a snack food in the ration scale of the service personnel stationed at high altitude regions in order to provide the benefits of incapacitating stress arising theretofore. However the efficacy of the CC-ARN bars with respect to their antioxidant potency in a biological system needs an in vivo evaluation with laboratory animals before the same are recommended for actual inclusion in the rations of our Armed Forces Personnel.

7. Conclusion

Armed ForcesPersonnel deployed at high altitude Himalayan regions are often disheveled both psychologically and physically due to the inescapable environmental conditions, strenuous field activities and associated metabolic alterations in their energy / nutrient requirements resulting in oxidative/ reductive stress. **V**itamins A, E, and C particularly from natural sources have since been found to control the negative influence of free radicals; two types of CC-ARN Bars in a ready-to-eat form with good sensory attributes and shelf stability have been successfully developed. Cereals, pulses, fruits, and vegetables which are known to be rich in vitamin C, β- carotene, vitamin E, iron and selenium processed with *Green Energy* have been used in the formulation, in view of their better micro nutrient density and longer storage stability.In the present study the CC-ARN bars have been evaluated for their nutritional quality, shelf stability and antioxidant potential. The CC-ARN bars showed significant losses in vitamin C content while the other antioxidant components were minimally affected during storage. In order to mitigate the stress arising in service personnel stationed at high altitude regions, the CC-ARN bars if introduced as a snack food in their rating scale wouldeffectively meet the additional antioxidants demand arising theretofore. However the efficacy of the CC-ARN bars with respect to their antioxidant potency in a biological system needs an in vivo evaluation with laboratory animals before the same are recommended for actual inclusion in the rations of our Armed Forces Personnel.

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