ISSN 1682-296X (Print)
ISSN 1682-2978 (Online)

Bio Technology

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Biotechnology

ISSN 1682-296X
DOI: 10.3923/biotech.2018.44.53

Research Article
Quality Attributes and Antioxidant Compounds of the Developed Spreadable Tofu Blends

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Abstract
Background and Objective: The use of soy as food ingredient has recently grown in food industry as a result of its health benefits, technological and functional properties. The objective of the research was to prepare functional products of spreadable tofu. **Materials and Methods:** Six formulated spreadable tofu with different flavors were prepared: Control without addition and with chopped green olives, ground black pepper+chopped green peppers, sugar, guava pulp and peach pulp. The spreadable tofu blends were subjected to chemical, physiological, microbiological and sensory evaluation to ensure different qualities. **Results:** Results demonstrated slight differences among treatments within the ranges of moisture, protein, fat, ash and carbohydrates. The antioxidants' activities varied from 66.98-80.80%. Total isoflavones fluctuated between 2181 and 3259 µg g^{-1}. All products were high in genistein, daidzein and low in isoformntine, biochainine. The highest percentages of phenolic compounds were ellagic, benzoic, catechin, pyrogallol, ferulic, naringin, hesperidin, quercetrin, naringenin and hesperetin. Among flavonoid compounds naringin, hesperidin, quercetrin , naringenin and hesperetin were scored as the highest values in tofu blends. All blends showed acceptable physicochemical properties. Fat separation was increased with extending storage period. Control spreadable tofu was less acceptable than the other blends. The microbiological investigation assured the safety of the blends. **Conclusion:** The present investigation confirmed that the formulated tofu blends exhibited high antioxidants' activities, acceptable physicochemical properties and assured its safety. The organoleptic attributes proved the superiority of the spreadable tofu blends with either fruit or vegetables addition compared to control.

Key words: Spreadable tofu, antioxidant activity, isoflavones, phenolic compounds, flavonoid compounds, physicochemical properties

Citation: Shafika Abd El-Hamid Zaki, Abeer Fouad Zayan, Hala Mahmoud Nagi and Amira Saber Abd El-Salam, 2018. Quality attributes and antioxidant compounds of the developed spreadable tofu blends. Biotechnology, 17: 44-53.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Soybean (*Glycine max*) has been called the "golden miracle bean" and was the world's foremost provider of protein, used for healthy food and industrial products[1].

The amino acid contents of soybean were 4.5% isoleucine, 7.8% leucine, 6.4% lysine, 1.3% methionine, 1.3% cysteine 4.9% phenylalanine, 3.1% tyrosine, 3.9% threonine, 1.3% tryptophan, 4.8% valine, 7.2% arginine, 2.5% histidine, 4.3% alanine, 11.7% aspartic acid, 18.7% glutamic acid, 4.2% glycine, 5.5% proline and 5.1% serine[2]. Further, it was assured that soybeans are high in quality, protein soybeans contain all the essential amino acids in adequate amounts needed for health and two- three servings of soy provide ~15-20 g protein and 50-75 mg of isoflavones[3].

Soybean protein modulated the expression of genes that regulated lipid metabolism and thyroid hormone, promoting weight loss[4]. This mechanism might attenuate metabolic changes that occur in obesity, which are related to insulin resistance[5].

The use of soy as food ingredient has recently grown in food industry as a result of its health benefits, technological and functional properties[6]. Soybeans found to be a rich source of phytochemicals and many of those compounds showed important beneficial effects on human and animal health. The important phytochemicals in soybeans for human health were phytoestrogens, mainly isoflavones[7].

Tofu used to be made from soybeans, water and a coagulant or curdling agent. It was not only the staple of Asian cuisines, but also became popular in Western cooking for its qualities and nutritive value[8].

Tofu contained 88% moisture, 6% protein, ~3% lipids, ~2% carbohydrates and 0.6% ash on dry weight basis. Isoflavones content of tofu was greatly reduced to be 532 mg isoflavones and having no cholesterol or lactose and small quantities of saturated fatty acids[9].

Tofu proved to have a high content of calcium that women would need during menopause. It helps to prevent hot flashes and high bone-loss risk related to menopause and during pre-menopausal stage and effective in preventing rheumatoid arthritis[10].

Tofu, being a significant source of selenium, could protect from colon cancer and reduce the risk of prostate cancer. Women consuming good amounts of tofu showed sixty percent less likely to have 'high risk' breast tissues than those getting fewer amounts or do not eat tofu[11].

Using tofu as least expensive substitute of milk cheese with vegetables and fruits containing several beneficial phytochemicals could open new avenues for developing acceptable tofu blends and help in reducing raw material costs. Thus, the present study aimed to determine the effect of mixing tofu with some commodities on the chemical composition, microbiological quality, physicochemical properties and sensory attributes of spreadable tofu products with different flavors to be used as functional foods.

MATERIALS AND METHODS

Soybean seeds (*Glycine Max.,* L., commercial variety) were obtained from Legumes Research Department, Field Crops Research Institute, Agriculture Research Center, Giza, Egypt.

All the added commodities (fruits and vegetables) were purchased from local market at Giza.

Plate count agar, McConky agar, malt agar and tryptone soy agar media were purchased from Difco Co (USA).

Preparation of tofu: The present study was carried out in Dairy Research Institute during the period December, 2015-December, 2017. Processing procedure of tofu is illustrated in Fig. 1[12,13].

Preparation of spreadable tofu with some commodities: Six blends of spreadable tofu with different flavors were formulated and prepared. The raw materials with added

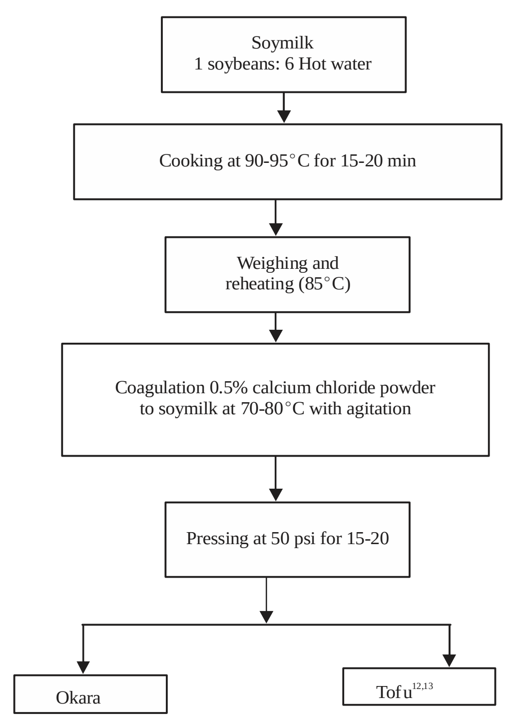

Fig. 1: Processing procedure of tofu products from soybeans

Table 1: Formulation of ingredients in different spreadable tofu blends

	Spreadable tofu blends (g)					
Ingredients	Control	T1	T2	T3	T4	T5
Soy curd	454.75	404.75	427.75	434.75	395.18	447.15
Skim milk powder	50	50	50	50	50	50
Whey powder	30	30	30	30	30	30
Palm oil	172.03	170.00	176.45	174.00	182.13	189.33
Q3	30	35	38	30	40	45
Emulsifying salts	25	25	25	25	25	25
Chopped green olives	-	50	-	-	-	-
Mix 0.2% ground black pepper and 2.5% chopped green peppers	-	-	27	-	-	-
Sugar	-	-	-	20	-	-
Guava pulp	-	-	-	-	200.00	-
Peach pulp	-	-	-	-	-	150
Water	238.22	235.25	225.9	236.35	77.69	63.52
Total	1000	1000	1000	1000	1000	1000

C: Control, spreadable tofu without any flavor, T1: Spreadable tofu with Chopped green olives, T2: Spreadable tofu with Mix ground black pepper and chopped green peppers, T3: Spreadable tofu with sugar, T4: Spreadable tofu with guava pulp, T5: Spreadable tofu with peach pulp

commodities and water were added consecutively in Laboratory Processing Kettle (Thermomix TM 31 made in Australia Pty Ltd 2010). The mixture was cooked for 10 min at 85-90°C using indirect steam at pressure 2-2.5 kg cm^{-2} then was hot filled into wide mouth glass jars and capped directly after filling. The spreadable tofu samples were analyzed at 0, 1, 2 and 3 months of storage in refrigerator (5±2°C). Formulation of the six tofu blends is shown in Table 1.

Chemical analysis: Moisture, total proteins, fat, salt and ash contents were determined as described in Official Methods of Analysis of Association of Official Analytical Chemists (AOAC)[14]. Carbohydrate content was calculated by subtraction of the sum of moisture, protein, fat and ash contents.

For determination, separation and quantification of phenolic acids and flavonoids compounds, samples were prepared according to Jakopic *et al.*[15]. All components were identified and quantified by comparison of peak areas with external standards[16].

Radical-scavenging activity by using 2,2-Diphenyl 1-picrylhydrazyl (DPPH) was performed using an ELX800 Microplate Reader (Bio-Tek Instruments, Inc.), according to Abdul-Wahab *et al.*[17].

Total phenolics were estimated based on procedures described by Maurya and Singh[18].

Flavonoids determination was performed according to Olajire and Azeez[19].

Physicochemical properties: Values of pH were measured using a digital pH meter (HANNA) with combined glass electrode (Electric Instruments Limited).

The oil separation index of spreadable tofu blend was determined according to Thomas[20].

Microbiological examinations: Total plate count (TPC) was recorded as colony numbers per gram of sample, yeast and mould count (Chikere and Udochukwu)[21], detection of coliform group, *Staphylococcus aureus* and *Listeria monocytogenes* as described by Katase and Tsumura[22].

Sensory evaluation: Sensory properties of samples were assessed by a panel using hedonic scale where 1-10 represents dislike extremely to like extreme. Sample of spreadable tofu blends were sensory evaluated for appearance (20 points), body and texture (40 points) and flavor (40 points).

Statistical analysis: The obtained data of the chemical components of each treatment and control were statistically analyzed by one-way analysis of variance and organoleptic scores were subjected to two-way of analysis. Least significant differences were estimated under a significance thresholds value of $p<0.05$. Data were analyzed using SPSS version 20.0 (SPSS Inc., Chicago, IL, USA).

RESULTS

Chemical composition of spreadable tofu products: Data in Table 2 show slight differences among the treatments within the ranges of moisture, protein, fat and ash (55.54-61.39, 15.56-16.93, 18.12-18.8 and 2.67-3.27%, respectively). Insignificant differences were found among both fat and ash contents of the blends. Calculated total carbohydrates ranged from 1.28-6.51%.

Antioxidants activities: Data in Fig. 2 indicate that antioxidants' activities fluctuated between about 66 and 80%

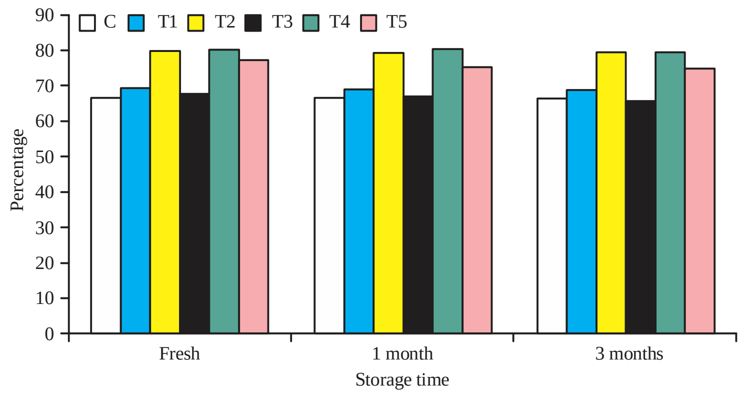

Fig. 2: Antioxidants' activities of different spreadable tofu products

C: Control, spreadable tofu without any flavor, T1: Spreadable tofu with Chopped green olives, T2: Spreadable tofu with mix ground black pepper and chopped green peppers, T3: Spreadable tofu with sugar, T4: Spreadable tofu with guava pulp, T5: Spreadable tofu with peach pulp

Table 2: Chemical composition of different spreadable tofu blends

Blends	Components (%) Moisture	T.S	Protein	F/DM	Fat	Ash	Carbohydrates
C	60.30^{b}	39.80^{c}	15.96^{b}	45.73^{b}	18.20^{a}	2.79^{a}	2.75^{c}
T1	61.39^{a}	38.61^{d}	15.56^{b}	48.69^{a}	18.80^{a}	2.97^{a}	1.28^{e}
T2	60.68^{a}	39.32^{c}	15.73^{b}	46.54^{b}	18.30^{a}	3.27^{a}	2.02^{d}
T3	58.28^{c}	41.72^{b}	15.68^{b}	38.54^{e}	18.12^{a}	2.67^{a}	5.25^{b}
T4	56.31^{d}	43.69^{a}	16.05^{b}	41.96^{c}	18.33^{a}	2.81^{a}	6.51^{a}
T5	55.54^{d}	44.46^{a}	16.93^{a}	41.05^{d}	18.25^{a}	2.96^{a}	6.32^{a}

C: Control, spreadable tofu without any flavor, T1: Spreadable tofu with chopped green olives, T2: Spreadable tofu with mix ground black pepper and chopped green peppers, T3: Spreadable tofu with sugar, T4: Spreadable tofu with guava pulp, T5: Spreadable tofu with peach pulp

Table 3: Isoflavones components of spreadable tofu blends

Spreadable tofu blends ($g\ g^{-1}$)	Isoflavones Control	T1	T2	T3	T4	T5
Genistein	1824.954	1767.046	1332.202	1503.312	820.799	1532.135
Isoformntine	162.230	165.381	177.608	127.882	125.860	123.790
Daidzein	1270.508	1176.002	1277.061	1237.499	1234.713	1161.526
Biochainine	1.467	1.932	1.639	1.168	0.020	0.086
Total	3259.159	3110.361	2788.510	2869.871	2181.392	2817.537

C: Control, spreadable tofu without any flavor, T1: Spreadable tofu with chopped green olives, T2: Spreadable tofu with mix ground black pepper and chopped green peppers, T3: Spreadable tofu with sugar, T4: Spreadable tofu with guava pulp, T5: Spreadable tofu with peach pulp

at zero time and after storage up to 3 months, which were close. The antioxidants' activities of all the blends were higher than that of control. The antiradical activity was evaluated from the plot of percentage DPPH showed increases in the treatments compared to control before storage and after storage up to 3 months, all treatments demonstrated slight decreases throughout storage. The highest activities were observed for T2 and T4, followed by T5 and then T2 blends with fruits, vegetables and spices. In contrast, the lowest values was recorded for T3 and control.

Isoflavones: The concentrations of isoflavones shown in Table 3 demonstrate that total isoflavones of spreadable tofu ranged from 2181-3259 $\mu g\ g^{-1}$. All treatments were high in genistein, daidzein and low in isoformntine and biochainine. The control sample demonstrated a higher concentration of isoflavones compared to other treatments.

Phenolic compounds: Twenty-one phenolic compounds of tofu spreadable blends were measured (Table 4). The phenolic compounds found in the different spreadable tofu blends included pyrogallol, gallic, 4-Aminobenzoic, protocatechuic, catechin, catechol, chlorogenic, epicatechin, p-OH-benzoic, caffeine, vanillic, caffeic, p-coumaric, ferulic, iso-ferulic, oleuropein, benzoic, ellagic, coumarin, salicylic and cinnamic. The highest values of phenolic compounds were in order as

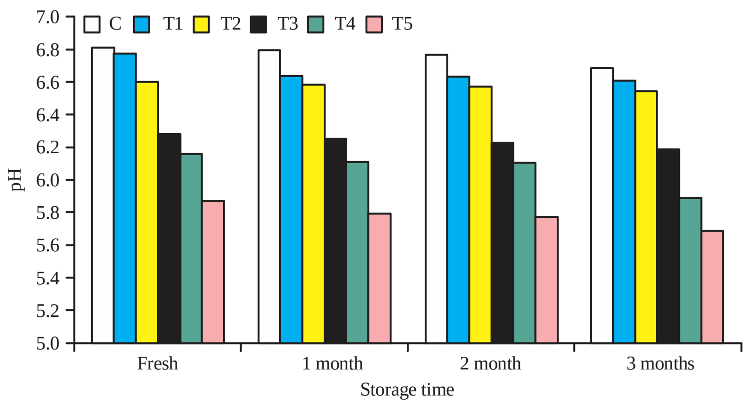

Fig. 3: The pH value of spreadable tofu products(%) throughout storage for 3 months

C: Control, spreadable tofu without any flavor, T1: Spreadable tofu with Chopped green olives, T2: Spreadable tofu with Mix ground black pepper and chopped green peppers, T3: Spreadable tofu with sugar, T4: Spreadable tofu with guava pulp, T5: Spreadable tofu with peach pulp

Table 4: Phenolic compounds in spreadable tofu blends

	Spreadable tofu blends					
Phenols (μg g^{-1})	Control	T1	T2	T3	T4	T5
Pyrogallol	1182.921	2314.384	1466.546	1125.792	1454.291	1881.394
Gallic	25.27	41.902	62.110	26.097	78.387	63.900
4-Aminobenzoic	54.466	367.465	216.651	103.445	181.752	221.562
Protocatechuic	31.994	35.004	36.155	21.268	22.556	88.209
Catechin	1596.386	2714.712	1777.500	725.368	1402.781	1752.139
Catechol	3.653	63.289	15.256	7.648	19.648	16.007
Chlorogenic	85.2	431.804	409.134	199.893	286.905	296.326
Epicatechin	18.832	88.423	22.983	47.391	52.221	64.001
p-OH- benzoic	76.414	159.367	94.555	65.309	111.784	193.352
Caffeine	310.319	372.482	328.556	1468.573	723.305	289.576
Vanillic	48.114	207.271	232.511	135.203	92.819	55.737
Caffeic	4.374	9.018	13.094	17.444	15.939	10.632
p-coumaric	52.375	141.403	62.564	107.968	101.064	92.385
Ferulic	809.974	327.817	399.599	806.727	454.251	675.824
Iso-ferulic	93.646	131.982	117.7	68.303	121.526	105.187
Oleuropein		214.518				
Benzoic	24822.868	12297.648	21074.692	15127.742	8729.857	25483.945
Ellagic	33996.304	895.591	9181.530	33852.586	5298.762	10950.991
Coumarin	29.416	56.320	18.294	38.434	28.032	23.783
Salicylic	76.846	173.095	205.963	144.234	93.694	221.189
Cinnamic	17.258	12.073	11.593	6.751	9.434	7.172

C: Control spreadable tofu without any flavor, T1: Spreadable tofu with chopped green olives, T2: Spreadable tofu with mix ground black pepper and chopped green peppers, T3: Spreadable tofu with sugar, T4: Spreadable tofu with guava pulp, T5: Spreadable tofu with peach pulp

follows: Ellagic, benzoic, catechin, pyrogallol and ferulic. Other phenolic detected compounds had very little amounts in soybean seed and tofu. Oleuropein was only found in T1.

Flavonoid compounds: Results in Table 5 show that in tofu blends, flavonoid compounds (naringin, hesperidin, rutin, rosmarinic, quercetin, naringenin, hesperetin, kaempferol and apigenin) were present. The highest values were scored for naringin (378-887), hesperidin (304-812), quercetrin (128-457), naringenin (118-174) and hesperetin (94-138) μg g^{-1}, while the lowest phenolic compound was kaempferol (4-32 μg g^{-1}).

Physicochemical properties of products

pH value: The data in Fig. 2 indicate that the pH values of fresh blends ranged from 5.88-6.82 and at the end of the storage period were 5.70-6.80. Generally, pH values of all treatment were higher than that of control before and after 3 months of storage. Results also indicated that adding the ratio of fruit additives in the blends, decreased pH value of the treatments.

Oil separation: Data in Fig. 3 indicate that spreadable tofu with pepper and guava had the lowest fat separation index

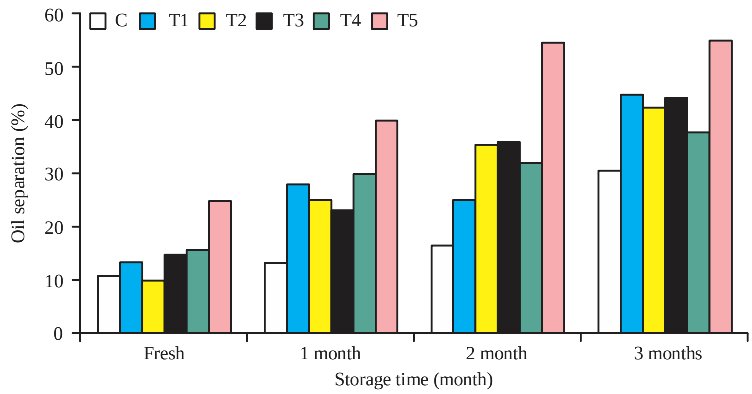

Fig. 4: Changes in oil separation of spreadable tofu products (%) throughout storage for 3 months

C: Control, spreadable tofu without any flavor, T1: Spreadable tofu with chopped green olives, T2: Spreadable tofu with mix ground black pepper and chopped green peppers, T3: Spreadable tofu with sugar, T4: Spreadable tofu with guava pulp, T5: Spreadable tofu with peach pulp

Table 5: Flavonoid compounds in spreadable tofu blends

	Spreadable tofu blends					
Flavonoids (μg g^{-1})	Control	T1	T2	T3	T4	T5
Naringin	887.055	428.001	378.079	862.106	787.815	740.405
Hesperidin	606.376	304.883	777.304	502.467	812.685	599.319
Rutin	59.380	45.016	89.959	58.561	77.495	88.445
Rosmarinic	6.439	1.402	3.099	3.934	5.003	9.154
Quercetrin	309.821	223.798	177.906	303.567	128.097	457.462
Quercetin	11.400	8.462	17.148	19.014	17.481	95.149
Naringenin	157.479	118.136	134.001	135.346	173.374	174.349
Hesperetin	119.991	94.867	103.114	111.163	107.876	138.904
Kaempferol	4.018	6.960	7.052	9.524	32.862	21.638
Apigenin	11.220	6.478	25.631	13.133	44.608	30.211

C: Control spreadable tofu without any flavor, T1: Spreadable tofu with chopped green olives, T2: Spreadable tofu with mix ground black pepper and chopped green peppers, T3: Spreadable tofu with sugar, T4: Spreadable tofu with guava pulp, T5: Spreadable tofu with peach pulp

Table 6: Microbiological properties of spreadable tofu products (log CFU g^{-1})

Blends	TBC (Fresh)	TBC (3 Month)	Yeasts and moulds	Coliform group	*Listeria*	*Staphylococci*
C	ND	3.34	ND	ND	ND	ND
T1	ND	5.13	ND	ND	ND	ND
T2	ND	2.78	ND	ND	ND	ND
T3	ND	2.69	ND	ND	ND	ND
T4	ND	3.33	ND	ND	ND	ND
T5	ND	3.04	ND	ND	ND	ND

ND: Not detected, C: Control spreadable tofu without any flavor, T1: Spreadable tofu with chopped green olives, T2: Spreadable tofu with mix ground black pepper and chopped green peppers, T3: Spreadable tofu with sugar, T4: Spreadable tofu with guava pulp, T5: Spreadable tofu with peach pulp, TBC: Total bacteria count

compared to the other samples. The fat separation was increased with extending the storage period.

Microbiological properties: Obtained data in Table 6 showed that yeasts and molds, coliform groups, *Listeria* and *Staphylococci* were not detected in all the samples throughout the storage period. Spreadable tofu product after 3 months of storage (C, T1, T2, T3, T4 and T5) had 3.34, 5.13, 2.78, 2.69, 3.3 and 3.04 log CFU g^{-1}, respectively.

Sensory evaluation: Data in Table 7 show that the sensory test of spreadable tofu blends proved the superiority of green olive sample compared to pepper sample for flavor and total acceptability. Meanwhile, guava sample showed significantly higher acceptability scores than peach ($p>0.05$). However, control spreadable tofu was less significantly acceptable than all the other blends ($p>0.05$). All organoleptic properties of the spreadable tofu blends except the appearance of T4 were significantly decreased ($p>0.05$) after 3 months storage due to the effect of storage.

Table 7: Sensory evaluation of spreadable tofu products during storage (3 months)

Spreadable tofu blends	Flavour (40)				Body and Texture (40)				Appearance (20)				Total acceptability (100)			
	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3
C	32.0^{C-e}	31^{D-f}	28.0^{G-h}	18.0^{J-j}	33.0^{B-d}	32.0^{C-e}	30.0^{E-f}	24.0^{H-h}	15.0^{B-e}	15.0^{B-e}	13.0^{E-f}	12.0^{F-f}	80.0^{E-e}	78.0^{F-f}	71.0^{G-g}	54.0^{I-i}
T1	37.0^{A-a}	35^{A-b}	33.0^{B-e}	25.0^{I-i}	35.0^{A-b}	35.0^{A-b}	34.0^{A-c}	27.0^{G-g}	17.0^{A-b}	16.0^{A-c}	16.0^{A-c}	15.0^{B-e}	89.0^{A-a}	86.0^{B-c}	83.0^{C-e}	67.0^{H-h}
T2	33.0^{B-e}	32^{C-e}	28.0^{G-h}	26.0^{H-i}	35.0^{A-b}	34.0^{A-c}	29.0^{F-g}	28.0^{F-g}	16.0^{A-c}	15.0^{B-e}	15.0^{B-e}	15.0^{B-e}	84.0^{C-d}	81.0^{D-d}	72.0^{G-g}	69.0^{H-h}
T3	35.6^{A-a}	35^{A-b}	33.6^{B-d}	26.0^{H-i}	33.0^{B-d}	32.6^{C-d}	31.8^{D-e}	27.6^{G-g}	16.0^{A-c}	15.0^{B-e}	14.8^{C-e}	13.8^{D-f}	84.0^{C-d}	83.2^{C-e}	80.2^{E-e}	67.4^{H-h}
T4	36.6^{A-a}	35^{A-b}	28.8^{F-h}	26.2^{H-i}	35.6^{A-a}	35.2^{A-a}	35.0^{A-b}	27.2^{G-g}	17.6^{A-a}	17.4^{A-b}	15.8^{A-d}	15.6^{A-d}	89.8^{A-a}	87.6^{A-b}	79.6^{F-f}	69.0^{H-h}
T5	34.4^{A-c}	33^{B-e}	30.8^{E-g}	26.8^{H-i}	36.4^{A-a}	34.4^{A-c}	32.0^{C-e}	28.2^{F-g}	17.2^{A-b}	17.0^{A-b}	15.8^{A-d}	14.0^{C-f}	88.0^{A-b}	84.4^{C-d}	78.6^{F-f}	69.0^{H-h}

Means with unlike superscript letters were significantly different (α = 0.05), C: Control spreadable tofu without any flavor, T1: Spreadable tofu with 5% chopped green olives, T2: Spreadable tofu with 2.7% mix ground black pepper and chopped green peppers, T3: Spreadable tofu with 2% sugar, T4: Spreadable tofu with 20%guava pulp, T5: Spreadable tofu with 15% peach, 0: Fresh, 1: 1 month, 2: 2 month, 3: 3 months

DISCUSSION

The moisture contents of the prepared tofu blends were in harmony with those of tofu creamy cheese[23]. A food products containing 1-25% fat was defined as low fat, the prepared spreadable tofu blends contained about 18% could be categorized as low-fat products[24]. Total carbohydrates were in the same line with Nazim *et al.*[9].

Regarding the antioxidant activity, the increase of the Free Radical Scavenging Activities (FRSA) for different treatments resulted from the added materials. These results are in harmony with those of Huang *et al.*[25]. Tofu prepared with garcinia extract showed high FRSA (82.1%), due to the polyphenolic compounds present in fruit extracts[26].

The control sample showing a higher concentration of isoflavones compared to other treatments might be due to the higher percentage of tofu in control. The major compounds in all the prepared blends reflected the compounds in tofu that were close to those of Chung *et al.*[27]. The high contents of genistein, daidzein and the low contents of isoformntine, biochainine confirmed those of Chung *et al.*[27].

The slight differences of isoflavones composition compared with other studies on soybean products could be ascribed to environmental and botanic characteristics and process technologies of analyzed samples[28].

Positive effects of isoflavones on heart health, bone health and post-menopausal symptoms effects are highly attractive to the functional foods market[29,30].

The presence of oleuropein in T1 only attributed to the addition of olives, a distinctive compound in olive fruits and not appearing in the rest of the other treatments, confirmed by Omar[31], who noted antioxidant, anti-inflammatory, anti-atherogenic, anti-cancer, antimicrobial and antiviral of oleuropein. Bulotta *et al.*[32] concluded that oleuropein showed cardioprotective properties against acute adriamycin cardiotoxicity and exhibited anti-ischemic and hypolipidemic activities. The study of Barbaro *et al.*[33], proved that adding oleuropein increased the ability of LDL to resist oxidation and at the same time reduced the plasma levels of total, free and esterified cholesterol.

Prasain[34], Otaki *et al.*,[35] and Thilakarathna and Rupasinghe[36] suggested that flavonoids showed a promise as useful adjuvants to prevent, delay and/or ameliorate several chronic diseases in aging humans including cancer, cardiovascular disease and cognitive impairments. Perhaps the greatest future impact of botanicals in age-related disease will be related to reducing the impact of the major contributors to the metabolic syndrome, since each of them is very closely linked to diet (e.g., excess fat and carbohydrate ingestion).

Physicochemical properties of products showing high pH value increasing of all treatment with tofu could be due to the high pH value of tofu used in the formula (6.00)[37]. The decrease of pH blends with fruits might be due to the limited growth and activity of fruit microflora and changes occurred in emulsifying salt form[37].

The oil index value depended on the state of fat and protein in resultant spreadable tofu emulsion, affected by type and amount of raw materials in the base formula, pH value, cooking time and temperature. Storage of samples increased the free oil in the product. Oiling was increased as the concentration of soy cheese increased[38,39], these findings were in the same line with those of previous studies of Azam[40] and Hussein *et al*.[41].

The fat separation was gradually increased with extending the storage period, which could be attributed to the nature of tofu protein that might affect the emulsification degree of the product. The oil index value depended on the state of fat and protein in resultant spreadable tofu emulsion, which could be affected by type and amount of raw materials in the base formula, pH value, cooking time and temperature. Storage of samples increased the free oil in the product confirmed by other researchers[41,42].

The microbiological properties confirmed that yeasts and moulds and coliform groups were not detected in tofu stored at refrigerator (4°C) even after 15 days of storage[43,44]. Heat treatment ultimately reduced the occurrence of the potentially harmful organisms and increased the shelf life of soy products[45].

As sensory evaluation, an important indicator of consumer preferences, all organoleptic properties of the spreadable tofu blends except the appearance of T4 were significantly decreased ($p>0.05$) after 3 months of storage due to the effect of storage period. The sensory panel test confirmed the similar trend noticed by El-Boraey[45] about beany taste and flavor that undoubtedly were the very important constituents to like or dislike a product as mentioned by Murugkar[13]. The presence of beany flavor and off smell of soy products appeared to be one of the biggest hindrances in its promotion as a healthy food. Food additives is known to reduce undesirable flavors to a minimum and maximize total acceptability for tofu, good color characteristics and was found highly acceptable by panelists[13].

CONCLUSION AND FUTURE RECOMMENDATIONS

The present study confirmed that the formulated tofu blends exhibited high antioxidants' activities, acceptable physicochemical properties and assured its safety. The organoleptic attributes proved the superiority of the spreadable tofu blends with either fruit or vegetables addition compared to control.

Consumers might be not aware of spreadable tofu blends and thus, introducing such products through marketing would be recommended. Further studies would be needed to use such blends in some popular foods such as bakery products as filling materials.

SIGNIFICANT STATEMENT

In the present study, new six tofu blends were formulated and prepared. The first blend contained only tofu without addition as control. In the five other blends vegetables and fruits were added to tofu to improve the taste, odor and its antioxidants activities. These blends could be used for its health benefits, technological and functional properties. The study would help researchers to use and incorporate such blends in some products to be used as inexpensive supplementary meals. Feeding several groups of populations would benefit health promotion of the whole society. This study confirmed that the formulated spreadable tofu blends exhibited high antioxidants' activities, acceptable physicochemical and organoleptic properties and assured its safety. The spreadable tofu blends proved the superiority of spreadable tofu blends compared to control.

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