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Development of Functional Beef Burgers with Pseudocereals and Study of their Physicochemical and Textural Properties

Fereshte Bahmanyar[1], Seyede Marzieh Hosseini[1], Leila Mirmoghtadaie[1]*, Saeedeh Shojaee_Aliabadi[1]*

1- Faculty of Nutrition Sciences and Food Technology, National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences, Tehran, Iran
* Corresponding authors (Le_mirmoghtadaie@sbmu.ac.ir)
* Corresponding authors (S_shojaee@sbmu.ac.ir)

Abstract

The objective of this paper is to appraise the quinoa and buckwheat seeds as pseudocereals to develop new beef burgers. In this study, three different formulations were prepared: one control sample with 15% mixture of bread crumb with soy protein, and two samples with 15% quinoa flour (QB) and buckwheat flour (BB), respectively. This replacement did not make significant difference between the different formulations in most of the physicochemical characteristics including moisture content, pH value, frying properties and water activity but emulsion stability and protein content were higher in the control sample than new formulations. Based on the results of texture properties, raw control sample showed significantly harder texture but BB showed harder texture after frying. Moreover, raw quinoa burger had a higher lightness value (L*). A comparison between the QB and BB burger showed significantly increase in protein and fat content, emulsion stability and lightness of QB. In conclusion, the replacing of bread crumb and soy protein mixture by buckwheat and quinoa flours in beef burger, especially by quinoa flour did not cause significant damage to burger properties and might be a suitable strategy to produce a new functional burger with comparable physicochemical and textural properties.

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Introduction

Nowadays, the tendency to consume ready -meals is increasing with the change in lifestyle (Abbasi Monjezi *et al.*, 2019). Also, healthy foods have attracted more attention due to increasing the awareness of consumers about the relationship between diet and health (López-Vargas *et al.*, 2014). At the same time, burgers are widely consumed as a meat product (Heck *et al.*, 2017). Moreover, soy protein and gluten as allergen compound are often used in these products which has limited their use in people with allergy and celiac patients (do Prado *et al.*, 2019). Therefore, the most useful and the best way to produce healthy products is to reformulate them to decrease the incidence of chronic disease and reduce allergic reactions (Öztürk-Kerimoğlu *et al.*, 2020). The use of non-meat materials in meat products is also an important factor in maintaining the quality, technological properties and nutrition of these products (Salarkarimi *et al*., 2019).

Additionally, quinoa (*Chenopodium quinoa* Willd) and buckwheat *(Fagopyrum esculentum* Moench) seeds as the pseudocereals are very noticeable in recent years (Bahmanyar *et al*., 2021). These pseudocereals are rich in essential amino acids and have high protein content (Öztürk-Kerimoğlu *et al*., 2020) and has high amounts of dietary fiber, minerals (zinc, iron, copper, magnesium and calcium), vitamins (C, E, B_1 and B_2), polyphenols and flavonoids (quercetin and rutin), (Cai *et al*., 2016; Lorusso *et al*., 2017; Park *et al*., 2016; Vega-Gálvez *et al*., 2010). Moreover, lack of gluten in buckwheat and quinoa protein makes it useful for celiac patients (Cai *et al*., 2016; Li & Zhu, 2017).

Therefore, quinoa and buckwheat seeds as pseudocereals with excellent nutritional properties can be suitable ingredients to be used in burgers formulation. Also, removing soy protein as an allergen compound and replacing it with these pseudocereals is a beneficial way to develop functional products. Thus, the main objective of this study was to evaluate the physicochemical and textural properties of functional burger formulation.

Materials and methods

Raw materials and beef burgers preparation

Quinoa and buckwheat seeds were obtained from OAB Company (Tehran, Iran) and were ground with electronic mill (Quadrumat Junior, Brabender, Germany), the final flour was maintained at 4±1 °C. Fresh beef without fat was bought from a butcher shop (Tehran, Iran) and was ground with meat grinder with 5 mm disk.

Three formulations of beef burgers including control sample, quinoa burger (QB) and buckwheat burger (BB) were prepared. Briefly, 60 g of the ground beef was mixed with 1 g spices, 1.5 g salt and 2.5 g onion powder. Afterward to obtain the hydrated flour, in the control sample, about 20 mL water was added to 15 g mixture of soy protein powder and bread crumb. In the samples of QB and BB, 15 g of quinoa or buckwheat flour were used in replace of the mixture of soy protein powder and bread crumb. Then all materials were kneaded by hand for 5 min and were molded. The ingredients of different beef burger formulations are shown in Table (1). Samples were packed in polyethylene covers and kept at -18 °C for the following mentioned analyses; each formulation was prepared in triplicate. Frying process was performed with low oil at 150 °C for 8 min which its internal temperature to get 70-75 °C. The samples were stored at room temperature until the internal temperature to get 25 °C.

Table 1. Ingredients of burgers with addition of quinoa and buckwheat flour (%)

Ingredient	Beef burgers		
	Control	Quinoa burger	Buckwheat burger
Beef meat	60	60	60
Water	20	20	20
Soy protein powder	6	0	0
Bread crumb	9	0	0
Quinoa flour	0	15	0
Buckwheat flour	0	0	15
Onion powder	2.5	2.5	2.5
Salt	1.5	1.5	1.5
Spices	1	1	1

Proximate composition and pH

The Moisture, lipid (Soxhlet), protein and (Kjeldahl) ash percent of raw samples were measured according to AOAC method in triplicate (Horwitz & Latimer, 2005) and the percentage of carbohydrates was obtained by subtracting their total from 100. The pH values of raw burger (mixture of sample and distilled water) were recorded by the pH meter (827 pH Lab Metrohm, Swiss) (Cuong & Chin, 2016).

Emulsion stability

The emulsion stability (ES) of burger batter was obtained by the method described by Ayadi *et al.* (2009). 10 g of sample were weighed in tubes (W_2) and centrifuged at 11,000 g for 30 min at 4 °C. After, the precipitated batter weighted (W_1) and ES was calculated according to the following equation:

$$ES\ (\%) = (W_1/W_2) \times 100 \quad (1)$$

Water activity

Water activity (a_w) of raw burger was determined according the method described by Heck *et al.* (2017) using Water Activity Meter (Rotronic Station Probe HC2-AW -USB Portable, Malaysia).

Frying properties

Samples were fried according to the method described above and frying properties including cooking loss, diameter reduction and shrinkage were measured. The cooking loss was obtained according to Zahid *et al.* (2020) as follows:

$$\text{Cooking loss } (\%) = [(\text{Raw weight}-\text{Fried weight})/\text{Raw weight}] \times 100 \quad (2)$$

Also, diameter reduction was determined as reported by Park *et al.* (2017) using the following equation:

$$\text{Diameter reduction } (\%) = [(\text{Raw diameter}-\text{Fried diameter})/\text{Raw diameter}] \times 100 \quad (3)$$

The shrinkage was calculated via following equation as reported by Alakali *et al.* (2010):

$$\text{Shrinkage } (\%) = \text{Raw thickness}-\text{Fried thickness} + [(\text{Raw diameter}-\text{Fried diameter})/(\text{Raw thickness}+\text{Raw diameter})] \times 100 \quad (4)$$

Texture analysis

Texture profile analysis (TPA) of raw and fried burger was performed according to the methods conformed by Choi *et al.* (2019) and Serdaroğlu *et al.* (2018) using a Texture analyzer TA-XT plus (Stable Micro Systems, United Kingdom). Texture parameters such as hardness (N), springiness (mm), cohesiveness, chewiness (N×mm) and gumminess (N) were recorded.

Color

The color parameter of raw and fried burger was measured using a Hunter Lab (Color Flex EZ; USA). The sample color was recorded with three repetitions and three readings from its surface in order to determine the values of lightness (L*), redness (a*) and yellowness (b*) (Sharma & Yadav, 2020).

Statistical analysis

SPSS software version 24 was used to analyze the data. After checking the normality of the data, one-way analysis of variance (ANOVA) and subsequent Duncan's tests ($\alpha = 0.05$) were applied to determine the significance of differences among burgers. Each formulation was prepared in triplicate and all tests were performed with three repetitions. Finally, the results were expressed as mean values±standard deviation.

Results and discussion

Proximate composition and pH

Table (2) shows proximate composition and pH of the burgers with addition of quinoa and buckwheat flours. There were no significant differences in moisture content among the different treatments. Similarly, Fernández-Diez *et al.* (2016) reported that the partial replacement of fat by boiling quinoa in dry cured sausage did not show significant effect on sample moisture content. The control sample showed slightly higher protein content (17.48%) compared with other formulations because of using isolated soy protein in the control sample formulation; it also had high ash content. This result confirms the data explained by do Prado *et al.* (2019), who observed higher protein value in soy protein burger as control sample. The fat content of burgers ranged from 1.87 to 2.41%; the highest amount was observed in QB sample. BB presented the highest carbohydrate content. Moreover, no significant differences were observed in the pH value among samples. Also, Fernández-Diez *et al.* (2016) did not observe significant differences in pH value between control sample and dry cured sausage treated with boiled quinoa.

Table 2. Chemical compositions (g/100 g) and pH of beef burgers

Burgers	Moisture	Protein	Fat	Ash	Carbohydrate	pH
Control	64.56±0.33[a]	17.48±0.12[a]	2.20±0.37[b]	2.79±0.10[a]	12.82±0.02[c]	5.96±0.01[a]
QB	64.61±0.12[a]	16.32±0.12[b]	2.41±0.05[a]	2.47±0.08[b]	14.16±0.09[b]	5.94±0.00[a]
BB	65.02±0.35[a]	15.34±0.13[c]	1.87±0.06[c]	2.36±0.07[b]	14.98±0.23[a]	5.96±0.02[a]

Different letters in a same column show significant different among burger (*P*<0.05) by Duncan test.

Table 3. Frying properties of beef burgers

Burgers	Cooking loss %	Diameter reduction %	Shrinkage %
Control	16.22±0.54[a]	12.56±0.31[a]	29.75±3.68[a]
QB	17.21±1.46[a]	10.80±0.78[a]	21.26±2.51[a]
BB	16.40±0.19[a]	11.74±0.46[a]	28.20±2.75[a]

Different letters in a same column show significant different among burger (*P*<0.05) by Duncan test.

Frying properties

Table (3) shows the effect of replacing quinoa and buckwheat flour on frying properties of beef burgers. The frying parameters including cooking loss, diameter reduction and shrinkage reflect the quality of meat products (Abdel-Naeem & Mohamed, 2016). No significant differences (*P*>0.05) were observed in frying properties of fried burgers. The cooking loss and diameter reduction ranged from 16.22 to 17.21 and 10.80 to 12.56, respectively. These parameters of samples treated with quinoa and buckwheat flours were almost similar to the control sample. Also, the shrinkage value of QB decreased (21.26%) but was not significant. Since, cooking loss and diameter reduction can indicate the amount of moisture and fat releases during the thermal process (Abdel-Naeem & Mohamed, 2016) and shrinkage can reflect the evaporation of water from the surface of the product, these results also can be related to the same ability of the samples to retain moisture. In other words, the amount of moisture and fat release from the samples was almost the same during the frying process and the replacement of soy protein and bread crumb by quinoa and buckwheat flours did not make a significant change in frying properties. Consistent with these results, do Prado *et al.* (2019) reported that the addition of tannin-free whole sorghum flour as an isolated soy protein replacer did not cause a significant effect on cooking loss and diameter reduction of burger samples. Also, Carvalho *et al.* (2019) reported that no significant differences were observed in the cooking loss and diameter reduction of the burgers being up to 3.75 g hydrated wheat fiber replaced with meat and fat.

Emulsion stability and water activity

The results of emulsion stability and water activity of samples batter are summarized in Fig. (1) and (2) respectively. There were significant differences (*P*<0.05) in emulsion stability of different treatments that was higher in control batter (90.76%) than the other samples and lower percentage (82.50%) of emulsion stability was observed in BB. The more stable emulsions are related to water from the network of protein and carbohydrate gels (Choe *et al.*, 2013). Thus, more stable emulsion in control batter could be due to the presence of soy protein isolated and its desirable emulsifying properties which could be increase water absorption. In this context, Senthil *et al.* (2002) noted that soluble protein in soya flour and its ability to bind the water led to increase the water absorption in the soya flour dough. Also, Tamsen *et al.* (2018) evaluated amaranth flour as a replacer of wheat flour in chicken nugget and reported maximum emulsion stability of sample with complete replacement of wheat flour by amaranth flour. They stated that this result might be due to the presence of surfaceactive agents, including globulin and polar lipids in amaranth flour and also high emulsifying properties of its proteins.

The comparison of emulsion stability of quinoa and buckwheat batter showed the stability of quinoa emulsion was significantly higher (*P*<0.05) than buckwheat emulsion. This result may be due to higher amounts of protein in QB (16.32%) compared to BB (15.34%).

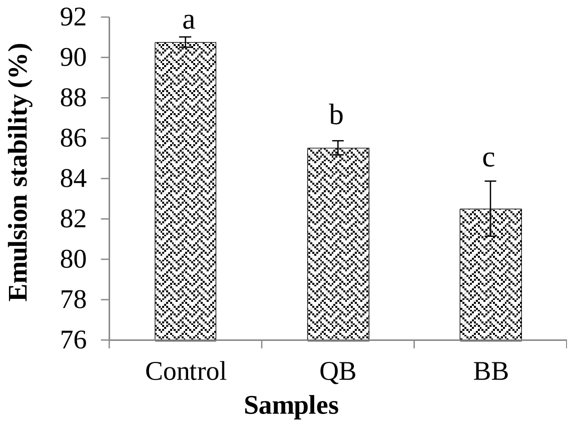

Fig. 1. Emulsion stability (%) of beef burgers. Different letters show no significant differences among burger (*P*<0.05) by Duncan test.

As can be observed in Fig. (2), there were no significant differences (*P*>0.05) in water activity of different burgers. Water activity is recognized as free water in the product that does not bind to other molecules involved in biological, physicochemical as well as spoilage reactions of the product (Raúl *et al*., 2018). Similar data were reported by Sánchez-Zapata *et al.* (2010) who did not report a significant difference in the water activity of pork burger treated with tiger nut fiber. Therefore, in the present study, no difference in water activity of different samples could be related to the same activity of meat mixture and fibers.

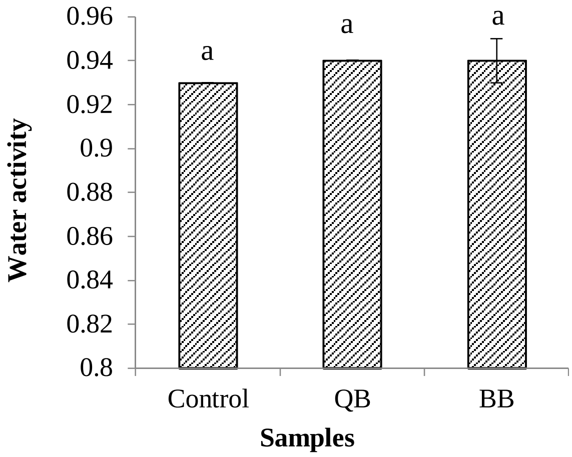

Fig. 2. Water activity of beef burgers. Different letters show no significant differences among burger (*P*<0.05) by Duncan test.

Texture profile analysis (TPA)

The results of texture analysis of raw and fried burgers are presented in Table (4). Comparison of texture profile between raw and fried burgers showed increase of all texture parameters except springiness of fried burgers. In this view, López-Vargas *et al.* (2014) noticed that the cooked burgers showed increased gumminess, hardness and chewiness and decreased springiness. Thus, according to these results, thermal process caused changes in soluble proteins, myofibrillar proteins and connective tissue of cooked meat texture (López-Vargas *et al*., 2014).

Table 4. Texture properties of raw and fried beef burgers

Burgers		Hardness (N)	Springiness (mm)	Cohesiveness	Chewiness (N×mm)	Gumminess (N)
Raw	Control	75.67±4.78^{a}	0.69±0.15^{b}	0.42±0.04^{b}	21.73±4.27^{a}	31.80±0.83^{a}
	QB	51.86±0.35^{b}	0.92±0.04^{a}	0.53±0.03^{a}	23.93±2.09^{a}	27.48±1.95^{b}
	BB	48.28±1.42^{b}	0.96±0.00^{a}	0.54±0.02^{a}	24.90±0.58^{a}	25.90±0.60^{b}
Fried	Control	222.52±4.26^{B}	0.59±0.01^{C}	0.44±0.04^{C}	57.53±4.82^{B}	97.32±8.40^{B}
	QB	251.02±21.90^{B}	0.86±0.02^{A}	0.70±0.08^{A}	151.78±22.57^{A}	177.08±25.00^{A}
	BB	346.30±12.00^{A}	0.80±0.01^{B}	0.56±0.02^{B}	156.53±10.11^{A}	194.92±10.25^{A}

Different small and capital letters in a same column show significant difference among raw and fried burger by Duncan test (*P*<0.05), respectively.

Table 5. Color parameters of raw and fried burgers

Burgers		Lightness (L*)	Redness (a*)	Yellowness (b*)
Raw	Control	41.13±0.30^{c}	8.77±0.20^{a}	20.83±0.35^{a}
	QB	55.38±1.06^{a}	8.63±0.09^{a}	18.74±0.29^{b}
	BB	49.52±0.90^{b}	8.83±0.11^{a}	20.42±0.36^{a}
Fried	Control	35.76±0.56^{A}	7.84±0.19^{AB}	16.79±0.37^{A}
	QB	37.24±0.55^{A}	7.18±0.54^{B}	15.97±0.32^{A}
	BB	32.46±2.20^{B}	8.47±0.61^{A}	13.95±1.10^{B}

Different small and capital letters in the same column show significant differences among raw and fried burger by Duncan test (P<0.05), respectively.

Among raw burgers, the control sample had higher hardness and more gumminess, but no significant difference was observed in chewiness of different raw burgers. All textural parameters of control fried burgers were reduced (P<0.05), except hardness (decreased but not significantly), compared to other fried formulations. These results could be due to from higher protein content of control sample compared to other treatments, which led to more water and oil absorption and thus textural parameter reduction. In this context, Ruiz-Capillas *et al.* (2012) observed increase in chewiness and hardness with decreasing fat in fermented sausages containing Konjac gel. Moreover, the non-covalent bonds between amino acid of meat myofibrillar proteins, including glutamic acid, aspartic acid and lysine with charged amino acids of quinoa and buckwheat flour led to an increase textural parameter of QB and BB (Cai *et al.*, 2016; Tamsen *et al.*, 2018; Valencia *et al.*, 2009). Contrary to these results, Öztürk-Kerimoğlu *et al.* (2020) observed that using quinoa in sausages as partial beef fat replacers caused a significant decrease in hardness that because of the increase of free water in the sample with low fat. Therefore, it can be concluded that the use of quinoa as a fat substitute reduced the hardness of meat products, but it uses as a substitute for bread crumb and soy protein powder in fried burgers increased the hardness.

A comparison between the texture properties of raw QB and raw BB showed that there were no significant differences between the textural parameters of these samples (P>0.05). Also, no significant differences were recorded in chewiness and gumminess of fried QB and BB, but the hardness of fried BB increased significantly (P<0.05) compared to fried QB. Since meat products are rich of the protein, interactions between carbohydrate and protein have been an important effect on the product functional properties (Basanta *et al.*, 2018). Therefore, harder texture of the BB could be due to its higher carbohydrates content and higher ability of construction of gel network. Similarly, Soltanizadeh & Ghiasi-Esfahani (2015) observed the hardness and compression force of burger containing *Aloe vera* increased duo to a lot of polysaccharides in *Aloe vera* that could make a weak gel.

Color measurement

The effects of quinoa and buckwheat flour on color parameters of raw and fried beef burgers are summarized in Table (5). The raw control sample showed lower L* (P<0.05) compared to QB and BB. The b* value this sample also increased but was not significant compared to BB .This result may be due to the lower amount of Carbohydrate in the control sample (according to Table (2)). In the same vein, do Prado *et al.* (2019) investigated the replacement effect of isolated soy protein with tannin and tannin-free whole sorghum flours in burger and observed that the a* and b* values increased in the control sample. They believed that lack of starch in soy protein samples was the reason for these results. Also, in raw QB the L* increased and b* value decreased (P<0.05).

However, these differences did not observe for fried burgers. Comparing the raw and fried burgers exhibited that the L* and b* of all samples decreased while a* value of burgers increased after cooking because of the maillard and caramelization reactions happened during the thermal process. In this respect, Hunt *et al.* (1999) reported that water release, myoglobin state changes, and the maillard reaction during the cooking process can be effective in reducing the lightness of cooked meat products. Similarly, do Prado *et al.* (2019) reported that L* of burgers containing soy protein isolated after cooking was reduced.

Conclusions

This research demonstrates a strategy for producing new meat product formulation using pseudocereals as sources of high quantity and quality protein. The results of this study showed that the replacement of bread crumb and soy protein powder with buckwheat and quinoa flour did not make a significant difference in moisture contain, pH value, frying properties and water activity of the samples. Also, no significant differences were observed in hardness between the fried quinoa burger and control samples. Raw quinoa burger had a higher lightness index (L*) while higher protein content and emulsion stability were observed in control sample compared to other formulations. The comparison between the buckwheat burger and quinoa burger showed that protein and fat content, emulsion stability and lightness significantly increased in quinoa burger compared to buckwheat burger while buckwheat burger had a harder texture. Overall, based on the results, the buckwheat and quinoa flours can be selected as substitute of bread crumb and soy protein in functional beef burger formulation.

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Author contributions

Fereshte Bahmanyar: Data collection, Writing the draft of the manuscript; **Seyede Marzieh Hosseini:** Data analysis, Data analysis and interpretation; **Leila Mirmoghtadaie:** Revising and editing the manuscript, Supervising the study, Approval of the final version; **Saeedeh Shojaee_Aliabadi:** Presenting the research idea and study design, Supervising the study.

Conflict of interest

There is no conflict of interest based on the writers.

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بهبود همبرگر فراسودمند باکمک شبه‌غلات و مطالعۀ خواص فیزیکوشیمیایی و بافتی آنها

فرشته بهمنیار[1]، سیده مرضیه حسینی[1]، لیلا میرمقتدایی[1*]، سعیده شجاعی علی‌آبادی[1*]

1- گروه علوم و صنایع غذایی، انستیتو تحقیقات تغذیه و صنایع غذایی کشور، دانشکده علوم تغذیه و صنایع غذایی، دانشگاه علوم پزشکی شهید بهشتی، تهران، ایران

* نویسندۀ مسئول (Le_mirmoghtadaie@sbmu.ac.ir)

* نویسندۀ مسئول (S_shojaee@sbmu.ac.ir)

چکیده

در این پژوهش، از دانه‌های کینوآ و باکویت به‌عنوان شبه‌غلات برای تولید همبرگر فراسودمند استفاده شد. در این مطالعه، سه فرمولاسیون مختلف شامل نمونۀ شاهد حاوی 15 درصد مخلوط پروتئین سویا و آرد سوخاری و دو نمونۀ دیگر به‌ترتیب حاوی 15 درصد آرد کینوآ (QB) و آرد باکویت (BB) به‌عنوان جایگزین مخلوط پروتئین سویا و آرد سوخاری تهیه گردید. این جایگزینی در بسیاری از ویژگی‌های فیزیکوشیمیایی ازجمله میزان رطوبت، مقدار pH، خواص سرخ‌کردن و فعالیت آبی تفاوت معنی‌داری بین نمونه‌های مختلف ایجاد نکرد، اما پایداری امولسیون و میزان پروتئین در نمونۀ شاهد بیشتر از فرمول‌های جدید بود. براساس نتایج بافتی، نمونۀ شاهد خام به‌طور قابل‌توجهی سخت‌تر بود اما بعد از سرخ‌شدن نمونۀ BB بافت سخت‌تری را نشان داد. علاوه‌بر این، همبرگر خام کینوآ شاخص L^* بالاتری داشت. مقایسۀ بین نمونه‌های QB و BB نشان داد که میزان پروتئین و چربی، پایداری امولسیون و شاخص L^* به‌طور قابل‌توجهی در QB افزایش یافته بود. به‌طورکلی نتایج نشان داد جایگزینی مخلوط پروتئین سویا و آرد سوخاری با آرد کینوآ و باکویت در همبرگر به‌ویژه آرد کینوآ، آسیب قابل‌توجهی به خواص همبرگر وارد ننموده است و می‌تواند به‌عنوان یک استراتژی جدید برای تولید همبرگر فراسودمند با خواص فیزیکوشیمیایی و بافتی مناسب درنظرگرفته شود.

واژه‌های کلیدی: باکویت، فراورده‌های فراسودمند، کینوآ، همبرگر