



Scientific Research

**Use of millets flours for partial wheat replacement in production of reduced gluten
Baguette bread**

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ABSTRACT

Although millet flour lacks gluten, however it is a rich source of protein, amino acids, energy, vitamins and nutritional ingredients in comparing with other cereal grains. In addition, it is overfilled of dietary fibers, phytochemical materials and micronutrients as well. In current research the effect of millet and wheat flour combinations in bread making was evaluated at different percentages of substitutions (10, 30 and 50 %). Baking properties of different bread samples were evaluated and related parameters with bread quality including volume, height, textural attributes (hardness, adhesiveness and cohesiveness), bread color and sensorial characteristic analyzed and compared with control bread. Results revealed that height and volume decreased but bread hardness increased with increase in substitution level. Color indices decreased for crust; however similar behavior was not observed for crumb. Interesting results observed by sensorial analysis. Total acceptance was higher in comparison with control bread due to different texture and taste. But this total acceptance decreased with substitution. The results of current research revealed high potential of millet flour for further usage in different food formulation.

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1- Introduction

Millet flour is an important part of traditional food products in many Asian and African countries. After all, millet contains a high amount of nutritional energy and quality. Researchers have studied the nutritional properties of millet and their properties, but the use of millet in food products is minimal compared to wheat, and this is due to the lack of awareness of its nutritional value and functionality and the lack of information about millet processing. Therefore, it is necessary to evaluate the possibility of incorporating millet in food processing such as bakery products.[1].

The presence of gluten in dough products has a great effect on the rheological properties of dough and the production process and the final quality of gluten-free products. Gluten-free dough is less elastic than wheat flour dough and is very loose and difficult to work with. Gluten components include gliadin and glutenin proteins, which create the viscoelastic network of the dough. Gliadin proteins are elastic and have the task of being viscous and cohesive of the dough, and glutenin proteins have the task of stretching and elasticity of the dough, so the addition of millet flour due to the absence of gluten has a negative effect on the rheological properties of the combined flour dough.[2].

The main and important component in the bakery industry is wheat flour, which is an excellent source of energy and nutritional base, but lacks micronutrients, complex carbohydrates and fiber. The quality of wheat protein is poor in comparison with other grains[3][And it is especially related to the low level of lysine, methionine and threonine in wheat proteins]4[. Therefore, it is necessary to find a suitable alternative to reduce these harms in the baking industry. The preparation of flour dough and the production of baking products is a complex physical, chemical and biochemical process

and is greatly influenced by the components of flour.]5[.

Gluten consumption is not a problem for some people. But its consumption may cause problems for some people who have certain physical conditions such as celiac disease, gluten sensitivity, wheat allergy. Celiac disease is the most severe form of gluten intolerance. Celiac disease is an autoimmune disorder that sees gluten entering the body as a foreign invader. As a result, the immune system attacks gluten and the intestinal lining. This attack damages the intestinal walls and may cause nutrient deficiencies, anemia, digestive problems and other diseases. Gluten-free grains such as corn, rice, quinoa, sorghum, millet, cassava starch, and calendula are grains that can reduce the pathogenic effects of gluten and wheat allergy if they are replaced with wheat flour in bakery products.]5[.

Although the formation of gluten network is a unique feature of wheat flour protein, it is possible to replace part of this flour with other flours in baking products. For example, some researchers have produced baking products using rye, soy, etc. under the headings of gluten-free flour.]6 and 7[. However, the studies conducted on the use of millet flour are very limited.

In addition to replacing a part of wheat flour with millet flour in baking products, the main goal is to increase the nutritional value and functional characteristics of baking products. Adding such a substitute affects the quality of baking products, and also does not decrease the overall acceptability of the consumer. The most important challenge is determining the optimal limit of such a replacement in the baking industry of bakery products]8[.

Therefore, in order to better use millet in bakery products, it is important to evaluate and study the changes in its properties and characteristics during the baking process in the quality of bakery and baking products.

The aim of this research is to discover the possibility of producing bread based on millet by replacing wheat flour with a set of ratios of millet flour. The main goal of this replacement is to increase the nutritional and functional value of baking products and produce gluten-free products. Adding millet and increasing the amount of substitution will definitely affect the quality of baking.

2- Materials and methods

2-1- Materials

Millet was obtained from an area around Gonabad city, Razavi Khorasan province, and then it was carefully cleaned and its external particles such as stones and sand were removed, and then it was milled to obtain fine flour. All-purpose wheat flour was purchased from a local store.

2-1-1- Dough preparation and bread production process

Combined flours were prepared using wheat flour and millet flour in mixing ratios of 10%, 30% and 50%. Dough samples were produced by mixing 50 grams of combined flour with water. Millet flour was included in the bread dough and baking tests were done to understand the effect of millet flour in the bread production process. The production bread dough had the following formulation: 250 grams of flour - 3 grams of yeast - 15 grams of sugar - 12.5 grams of fat and 4 grams of salt. Ambient water temperature (approx $^{\circ}$ 22) was kept. Dough samples were mixed using a laboratory mixer (with constant speed and uniform rotation of the mixer). Dough mixing time (10 minutes) and dough stopping time (15 minutes) remained unchanged during the tests. In the next step, kneading was done, and after shaping the dough with a roller (baking mashad), the rolls were kept for 45 minutes in a greenhouse at 35 degrees Celsius to fully expand as a result of yeast activity. The baking process of bread was done at a temperature of 300 degrees Celsius and a time of 15 minutes. To apply the same

baking conditions, all the samples were placed in one floor of the oven (Mashhad 3-floor fixed baking oven made in Iran). Baked breads were naturally cooled to room temperature in 2 hours. The breads were packed in polyethylene plastic and were taken to the laboratory to perform the necessary tests]9[.

2-2- Methods

2-2-1- Physical characteristics of bread

After each baking, the bread was removed from the oven and cooled. Then the physical characteristics of the bread such as volume (according to the 2000 standard, AACC No. 30-54 of the rapeseed displacement method]10[) and height; It was measured manually.

2-2-2- Texture characteristics of bread

Texture characteristics of bread samples using texture analyzer (TA-XT, Stable Micro System, United Kingdom) was evaluated. The device was equipped with a cylindrical probe with a diameter of 25 mm and a force of 50 newtons. Bread tablets were prepared as cubes (2×2×2) and were tested. The cut slices were compressed to 50% of their thickness at a speed of 25 mm per minute. 5 repetitions were done and the average of the repetitions was reported. Hardness, adhesion and continuity parameters were calculated from the obtained curve]11[.

2-2-3- color evaluation

Bread crust and core were evaluated using image processing method. ValueL which indicates the darkness and lightness of the product was extracted. In order to measure this component, first a slice of 2 x 2 cm was prepared from the core and crust of the bread and it was photographed by a Canon scanner with a resolution of 300 pixels, and then the images were provided to the ImageJ software and the desired component was calculated.]12[.

2-2-4- Sensory evaluation of bread

Sensory evaluations of bread samples were performed by 25 evaluators using the 10-point hedonistic method. For this purpose, a coded slice of fresh bread was used. Sensory evaluations were from the point of view of appearance, color, taste, texture and overall acceptability. The acceptability of each parameter was evaluated from 1 to 10, and the product that got an average score of more than 5 for overall acceptability was reported as acceptable.

2-2-5- Data analysis

The results obtained from the tests performed on bread, based on the factorial design in a completely random block format, using the software SPSS (version 21) was evaluated. The samples included four consumption levels of millet flour (0, 10, 30 and 50%) and the average results were compared using Duncan's test at the 95% confidence level. Excel software was used to draw graphs.

3. Results and Discussion

3-1- Physical characteristics of bread

3-1-1- Bread height

Incorporating millet flour into bread dough affected the properties of bread. The addition of millet flour reduced the height of the bread loaf. The height of the loaves is shown in Table 1. The height of the bread decreased with the increase of millet flour in the bread dough, and the lowest decrease was observed in the replacement of 10%. Replacing 50% of millet flour in bread dough led to the production of low quality bread. The height of the buns decreased to the lowest level.

As can be seen in Table 1, the increase of millet substitution affects the height of the bread, but there is no significant difference between the control bread and the bread containing 10% millet flour. And this

indicates that millet bread has 10% height equivalent to Shahid bread.

The height of bread depends on the elasticity and strength of the gluten network in the dough, and the formation of this gluten network is mainly related to the presence of glutenin and gliadin fractions in flour (gliadin is responsible for viscosity and glutenin is responsible for viscoelasticity). The absence or small amounts of these protein fractions leads to elastic dough. Table 1 clearly shows that increasing the composition of millet flour decreased the height of the bread, this indicates that most elastic doughs are not capable of keeping the gas produced during the fermentation process and such a dough has a shorter rising time (Rise time) is faster compared to viscose paste. However, the dough disintegrates due to the lack of glutenin proteins (which are responsible for the viscoelastic properties of the dough).

Table 1 Height of breads at different substitutions levels of millet flours

Sample	Height (Cm)
Control sample	0.03 ^a ±6.81
10%	0.03 ^a ±6.55
30%	0.01 ^b ±5.21
50%	0.02 ^c ±4.11

2-1-3- Volume of bread

The volume of the breads was measured and the results are given in Table 2. The volume of breads in breads containing millet flour decreased. The largest volume of bread was observed in bread containing 100% wheat flour. The negative effect of millet flour on bread volume may be due to the reduction of gluten proteins in breads containing millet flour. Since millet flour does not contain gluten, these proteins are responsible for creating structure in dough products, and in this connection there are many confirming findings that strengthen this hypothesis. For example, the effect of sorghum varieties on bread quality was evaluated by Murad et al. (1984), 5 different sorghum varieties were considered for the research. Wheat flour was replaced by 10%, 20% and 30% sorghum flour and it was observed that the volume of bread decreased with the increase of sorghum flour.]13[.

In a study by Singh et al. (2012), bread was prepared using the combined flour of millet and wheat varieties with the addition of gluten. It was observed that the volume of the bread loaf improves with the increase of gluten content, which indicates the key role of gluten protein in creating a structure in the volume of bread.]14[.

Table 2 Volume of breads at different substitutions levels of millet flours

Sample	Volume (cm ³)
Control sample	1.1 ^a ±450
10%	1.3 ^b ±420
30%	2.1 ^c ±340
50%	1.5 ^d ±265

The height and volume of the bread is simply the result of how the dough expands and rises and retains gas during the fermentation process and during baking. Bread volume and bread height are also related to the ability of the dough to hold its shape during the baking process.

As it was observed, the volume of bread decreased with the increase of millet flour composition (Table 2). It was observed that the volume and height of the bread have a linear relationship with each other. During baking, it was observed that the surface of the bread did not wrinkle, especially in lower proportions of millet flour (10% and 30%). It was also observed that the volume of breads with more millet flour composition was less with the bread crust shrinking, which indicates the inability of the bread to retain gas during the baking process (due to the lack of gluten proteins). Increasing the composition of millet flour in the dough leads to an increase in the amount of starch in the dough, which makes the nature of the dough more elastic than viscoelastic, which is confirmed by the elastic and viscous moduli.

2-3- Texture characteristics of bread

One of the important parameters in bread consumer acceptability is bread texture. Hardness, elasticity, cohesion and stickiness are the most important textural characteristics of bread]15[. Hardness can be defined as the amount of force required to bite the bread and elasticity, the degree or extent to which the bread returns to its original size after compression. Stickiness is defined as the degree to which the bread sticks to the roof of the mouth, and consistency is defined as how the bread sticks together during chewing.]16[.

The hardness of the bread is the force required to compress the bread between the teeth and is expressed in newtons. Attachment depends on the degree and extent to which the material is held together during chewing. Adhesion depends on the work required to overcome the absorbing forces between the surface of the food substance and the surface of other objects that the food substance is in contact with, such as the tongue, the roof of the mouth, or

the teeth, and the work required to separate the food from a surface.]11[

1-2-3-hardness of bread

The results of the hardness of the bread samples are given in Table 3. The hardness of bread is affected by the combination of millet flour and the increase in the ratio of combination and replacement has resulted in more hardness of the bread texture (Table 3). Therefore, the combination of millet in wheat bread dough should be done to a certain extent and level in order to ensure the acceptable quality of the bread.

The incorporation of millet flour in bread affects the water absorption of the dough. Dough water absorption and bread hardness are inversely related. Decrease in water absorption leads to hard and rough dough. Increasing the composition of millet flour reduced the height of the bread, which in turn will lead to a porous and dense structure (compared to breads containing 100% wheat flour) and this can make the texture of the bread harder due to the reduction of air in the structure. increase and lead to a more porous and rigid structure.

These results are consistent with similar research results of other researchers. Among them, Maridola and colleagues (2007) investigated wheat and sorghum flour (0, 10, 20, 30, 40, 50 and 60%) in biscuit formulation. They showed that dough development and dough strength decreased with increasing sorghum flour substitution, while hardness, average breaking force of biscuits, and tear and disintegration energy increased.]17[.

Saha and colleagues (2011) used millet flour and wheat flour in biscuit formulation. Ratios of 30:70 and 40:60 millet flour and wheat flour were evaluated in dough and biscuits. They showed that in the proportion of 60% millet flour, the

hardness of biscuits increased compared to 30%.]18[.

Biscuits were produced by Chakraborty et al. (2011) with refined millet flour and wheat flour. They observed that increasing millet flour in the composition increased the hardness of biscuits, but increasing the baking time increased the overall acceptability. The recommended optimum amount of millet flour for biscuit production was 10%]19[.

Increasing the composition of millet flour increased the hardness of the bread (Table 3). In this research, 50% substitution caused the maximum hardness of the bread. No significant statistical difference was observed between 10% and the control sample, which shows that although wheat flour was replaced with millet flour, no significant difference was observed in the degree of hardness. Similarly, no significant difference was observed between 10% and 30%, but the hardness of 50% millet flour sample was significantly different from other samples. It shows that bread containing 50% millet flour is not suitable for the consumer market due to its high hardness. At the same time, sensory evaluations will reveal better details in this connection.

Table 3 Hardness of breads at different

Sample	Hardness (N)
Control sample	0.03 ^c ±1.81
10%	0.03 ^{bc} ±2.91
30%	0.05 ^b ±4.55
50%	0.02 ^a ±7.43

substitutions levels of millet flours

2-2-3-Continuity of bread

The sequence of bread samples is given in Table 4. The consistency parameter increased initially with the addition of millet flour, but eventually decreased with the further increase of millet flour, which is due to the lack of required gluten structures, which decreased with the addition of more millet flour in the dough.

As mentioned earlier, gluten proteins in dough are responsible for forming a single porous structure in bread. This porous structure determines the cohesiveness of the bread. The addition of millet flour in the dough leads to the reduction of gluten proteins and also modifies the starch fractions present in the dough, and such changes may affect the porous structure of the bread and change the consistency.

As can be seen from Table 4, there is no significant statistical difference between the control sample and the bread sample containing 10% millet flour, and this indicates that the bread containing 10% millet flour has the same continuous characteristics as the normal bread sample.

Table 4 Cohesiveness of breads at different substitutions levels of millet flours

Sample	Cohesiveness
Control sample	0.00 ^a ±0.091
10%	0.00 ^a ±0.10
30%	0.00 ^b ±0.045
50%	0.00 ^c ±0.025

3-2-3-stickiness of bread

The stickiness of bread showed a different behavior in comparison with the consistency parameter of bread. The stickiness of breads increased with the addition of millet flour in the formulation. The maximum amount of adhesion was obtained in the combination of 50% millet

flour (Table 5). The obtained stickiness values of breads containing millet flour were much higher than breads containing wheat flour (control sample), and this is basically due to the fact that millet in bread increases the starch fractions, which will lead to an increase in the stickiness of the final baked product.

A significant statistical difference was observed between the control sample and all samples containing millet flour in the stickiness parameter (Table 5), but no significant difference was observed between the three samples of 10%, 30% and 50% millet flour.

Table 5 Adhesiveness of breads at different substitutions levels of millet flours

Sample	Adhesiveness (mJ)
Control sample	0.01 ^b ±5.81
10%	0.01 ^a ±8.21
30%	0.01 ^a ±8.23
50%	0.02 ^a ±9.43

3-3- Color of bread

The color of bread is influenced by the composition of millet flour. The results of colorimetric parameters with characteristicsL It is given in Table 6. ValueL In the case of each sample, it states the amount of darkness of the product and whateverL If it is less, the product is darker. For a better understanding of the combination of millet flour on the color of the value breadL In bread, it was measured for both crust and bread core.

Parameter valuesL For the crust of breads, it decreased with the initial addition of millet flour, which indicated the fact that the darkness of the bread samples increased with the addition of millet flour. However, the color of the bread crust has increased with higher proportions of millet flour substitution, which indicates that the bread samples with millet flour are brighter.

There is a significant statistical difference between the control sample and the bread samples containing 10% millet flour, and similarly, a significant difference was observed between 10% and 50% millet flour, but this difference is not observed between the 30% and 10% samples.

The bread core showed a similar behavior with the bread crust. Composition of millet flour, amountsL The kernel of the bread decreased compared to wheat flour bread; But this reduction was minimal compared to the change in the color of the bread crust. Unlike the color of the bread

crusts, a significant difference was observed in the composition of millet flour between 10% and 50% substitution. These significant changes in color can be due to the fact that the core of the bread depends on the color of the components used in the first step, and millet flours are slightly darker than wheat flours. Of course, more research is needed to determine which millet flour compounds affect the color of the bread during the baking process and whether such a color deviation affects the consumer's desire.

Table 6 L value of crust and crumb for breads at different substitutions levels of millet flours

Sample	Crumb	Crust
Control sample	2.33 ^a ±72.53	2.03 ^b ±53.16
10%	2.01 ^b ±67.52	1.43 ^c ±41.31
30%	1.67 ^c ±66.55	1.30 ^c ±48.25
50%	1.98 ^d ±61.25	1.14 ^a ±71.99

3-4- Sensory evaluations

Sensory evaluations of bread were done to determine the acceptability of bread containing millet mixed with wheat flour and the results are given in Table 7. The scores of sensory evaluations were also compared with the device tests conducted in this research and the results are given in figures 1 and 2. Sensory evaluations showed interesting results. The overall acceptability of millet flour bread was higher than wheat

flour bread alone due to its different pleasant taste and texture. However, this overall acceptability decreased with the increase of millet flour in the composition.

Millet flour bread with 10% substitution showed a higher general acceptability and better taste in comparison with millet flour breads with 30% and 50% substitutions. The panelists also pointed out that millet bread showed less chewiness compared to wheat bread.

Table 7 Sensorial evaluation of breads at different substitutions levels of millet flours

Sample	Total Acceptance	Flavor	Taste and Odor	Crumb Color	Crust color	Texture	Appearance
Control sample	0.68 ^a ±8.56	0.55 ^c ±7.96	0.45 ^c ±7.86	0.65 ^a ±8.00	0.45 ^a ±7.66	0.85 ^a ±7.76	0.60 ^a ±8.41
10%	0.55 ^a ±8.48	0.51 ^a ±8.58	0.41 ^b ±8.12	0.61 ^b ±7.68	0.51 ^b ±7.28	0.81 ^a ±7.68	0.55 ^b ±7.77
30%	0.54 ^b ±7.77	0.44 ^b ±8.22	0.44 ^a ±8.22	0.54 ^c ±7.22	0.54 ^b ±7.12	0.50 ^b ±7.22	0.50 ^c ±6.82
50%	0.61 ^c ±6.45	0.55 ^d ±7.25	0.35 ^d ±7.15	0.55 ^d ±6.20	0.35 ^c ±6.25	0.45 ^c ±6.15	0.45 ^d ±6.35

Correlation between textural characteristics of millet flour breads when compared with sensory results (Figure 1) shows that the superiority of texture in terms of sensory evaluation decreased with increasing substitution of millet flour.

Hardness is the first general characteristic that is felt by panelists or consumers and indicates the degree of hardness or softness of the material, and this feeling of softness/hardness is significantly related to overall acceptability. Increase in hardness,

increase in stickiness, and decrease in consistency with the increase in the replacement rate of millet flour led to a drop in textural preferences of breads containing millet flour.

QuantitiesL The crust and core of the bread were correlated with the results of the

sensory evaluations (Figure 2). The color of the core of the bread obtained the same scores as the color of the crust in the sensory evaluations, and it showed decreasing scores with increasing substitution of millet flour.

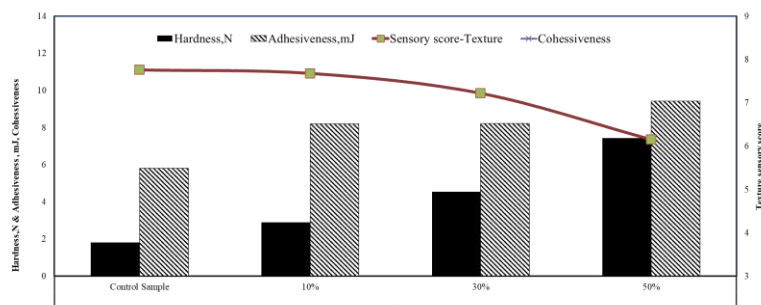


Fig 1 Sensorial evaluation versus texture profile of bread containing millet flour

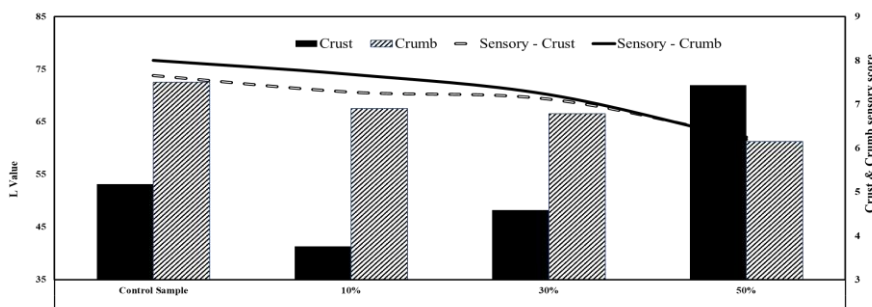


Fig 2 Sensorial evaluation versus L value of bread containing millet flour

4- General conclusion

This research was done to evaluate the behavior of millet flour in bread formulation. Dough efficiency and baking quality were affected by millet flour composition. Increasing substitution of millet flour in bread dough reduced the

baking properties of the dough. More substitutions of millet flour from bread led to harder bread and scored less in sensory evaluations. However, sensory evaluators preferred breads containing millet flour due to the pleasant taste and different texture.

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استفاده از ارزن بعنوان جایگزین آرد گندم در تولید نان باگت با گلوتن کاهش یافته

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اطلاعات مقاله	چکیده
تاریخ های مقاله :	آرد ارزن اگر چه فاقد گلوتن می باشد، اما از نظر ارزش غذایی در مقایسه با سایر دانه های غلات منبع غنی از پروتئین، اسیدهای آمینه ضروری، انرژی، ویتامین ها و مواد مغذی می باشد. علاوه بر آن سرشار از فیبرهای رژیمی، مواد فیتوشیمیایی و ریزمغذی هاست. در پژوهش حاضر اثر ترکیب آرد ارزن و گندم در تولید نان در سطوح جایگزینی مختلف (۱۰، ۳۰ و ۵۰ درصد) مورد بررسی قرار گرفت. خصوصیات پخت نمونه های مختلف ارزیابی شد و پارامترهای مرتبط با خواص نان از قبیل حجم، ارتفاع، خصوصیات بافتی (سختی، چسبندگی و پیوستگی)، رنگ نان و خصوصیات حسی اندازه گیری و با نان آرد گندم مقایسه شد. نتایج حاصل از تحقیق بیانگر آن بود که با افزایش سطوح جایگزینی آرد ارزن در فرمولاسیون، ارتفاع و حجم نان کاهش، سختی نان ها افزایش و مقادیر شاخص رنگی برای پوسته نان کاهش یافت، اما مغز نان رفتار مشابهی با پوسته نشان نداد. ارزیابی های حسی نتایج جالب توجهی را نشان داد. مقبولیت کلی نان آرد ارزن بدلیل طعم متفاوت و بافت، از نان آرد گندم بالاتر بود، اما این میزان مقبولیت کلی با افزایش آرد ارزن در ترکیب کاهش یافت. نتایج تحقیق حاضر بیانگر پتانسیل بالای آرد ارزن برای استفاده در فرمولاسیون های مواد غذایی مختلف است.
کلمات کلیدی: آرد ارزن، آرد گندم، نان، ارزیابی حسی، بافت	
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