豚皮を用いた膨化食品の開発とその品質について

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Development and Quality of Puffed Food from Pigskin

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The procedure to make puffed snack food from pigskin of animal by-products was evaluated to make efficient use of the skin. Immersing pigskin after the removal of hair in water at 100℃ for 60 min successfully reduced fat and degraded tissue integrity without altering the shape of the skin. The defatted pigskin was dried at 80℃ for 4 h to reduce the water content to approximately 2% before being deep-fried at 200℃ or baked at 200℃. The resulting puffed pigskin had high-protein content and was rich in collagen. Furthermore, the baked pigskin was low in fat content. Results of sensory evaluation were satisfactory regardless of whether pigskin samples were puffed by deep-frying or baking. These results demonstrate the possibility that pigskin from animal by-products can be used to produce a novel food by a food additives-free method using an ordinary food processing machine.

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Key words : *animal by-products, pigskin, baking, puffed food*
畜産副産物，豚皮，焙焼，膨化食品

The meat industry generates animal by-products such as skin, bones, internal organs, and blood. The ratio of such by-products to live body weight is generally high ; for example, approximately 1 : 2 for pigs. Although useful ingredients contained in animal by-products are used in food, medical, and other industries[1], the use of such by-products is low. In addition, the volume of animal by-products in Japan has been increasing in line with the recent increase in meat consumption[2]. Thus, the impact of animal by-products on the environment and the cost required for appropriate disposal are serious concerns.

The skin of livestock has been used to produce leather for a long time[3]. Because it is rich in collagens and elastin, which are the main proteins in animal connective tissue and essential for the maintenance and protection of individual cells and organisms[1),3)~5)], it also serves as a source of these proteins[1),3),5),6)]. However, extraction and purification procedures use chemicals[3)~6)] ; therefore, the management of effluent is an additional problem. Furthermore, the amount of skin utilized is only a part of the total animal by-products produced.

Japan's food self-sufficiency rate, calculated by calorific content, was approximately 40% in 2008[2),7)], which was the lowest in major industrialized countries. This low food self-sufficiency can be explained by the low livestock self-sufficiency rate, which in turn can be attributed to the heavy dependence on imported livestock feed[2),8)] and the delay in development of methods enabling high utilization of animal by-products. Here, we aimed to find environmentally friendly methods that enable full utilization of pigskin waste. We established a chemical-free method for converting pigskin to flavorsome food with appropriate properties and evaluated the quality of the processed pigskin.

Materials and Methods

1. Materials

A skin sample was obtained from a slaughtered triple-cross breed pig (Landrace × Large White × Duroc) which was dehaired and skinned after immersing in a water bath at 65℃ for 2 ～ 3 min. The resulting skin samples were stored in a freezer and thawed at room temperature before use.

2. Defatting

Defatting was performed by immersing pigskin samples in hot water. Briefly, pigskin samples were heated in an autoclave (HV-85 ; Hirayama Manufacturing Co., Saitama, Japan) in water (pigskin : water = 1 : 10 w/w) at 80℃, 100℃, or 120℃ for 20～80 min.

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3. Drying

The defatted pigskin samples were dried at 80℃ for 1 ～ 9 h using a forced-air dryer (PS-120 ; ShimizuScientific Instruments MFG Co., Ltd., Tokyo, Japan).

4. Puffing

Two methods were used for puffing. The defatted and dried pigskin samples were deep-fried in canola oil at 200℃ using an e lectric f ryer (EFK-A 10 ; Zojirushi Co., Osaka, Japan) or baked in a bread baking oven (NCGCH1 ; Sanko Machinery Co., Ltd., Tokyo, Japan) at 200℃.

5. Proximate analysis

Contents of water, protein, fat, and ash from the untreated pigskin samples and from those after each step were analyzed by the standard method according to the official AOAC procedures[9].

6. Expansion rate measurement

The expansion rate of puffed pigskin samples were measured according to the method reported by Aizawa *et al.*[10] Briefly, pigskin samples before puffing were placed into a measuring cylinder containing an appropriate volume of water, and the change in water level was taken as the pre-puffing pigskin volume. The post-puffing volume was measured in a similar manner, and the expansion rate was obtained by dividing the post-puffing volume by the pre-puffing volume. Because pigskin became porous after puffing, it was immersing in a paraffin bath to coat the surface to prevent water penetration. The volume of paraffin used for the coat was deduced from the gross volume to obtain the net volume of the post-puffing pigskin.

7. Observation of appearance and tissue

Appearance and tissue of the pigskin samples before and after puffing were examined using a digital camera (GR DIGITAL ; Ricoh Co., Ltd., Tokyo, Japan) and a t abletop microscope (TM-1000 ; Hitachi High-Technologies Co., Tokyo, Japan).

8. Determination of collagen

Collagen levels were determined by measuring the levels of hydroxyproline, the unique amino acid residue in collagen, according to the method reported by Kivirikko *et al.*[11] Based on the fact that pigskin collagen contains 125 hydroxyproline residues for every 1,000 amino acid residues[12),13)], collagen levels were obtained by multiplying the hydroxyproline levels by a factor of 8 (1,000/125).

9. Sensory evaluation

Shape, color, aroma, texture, taste, and overall impression of pigskin samples puffed by either deep-frying or baking were judged by 21 panelists (9 males and 12 females, aged 29～55 years). A 7-point scale was used for evaluation as follows. －3 : very poor ; －2 : poor ; －1 : fairly poor ; 0 : fair ; ＋1 : fairly good ; ＋2 : good ; ＋3 : very good. A puffed corn snack, a commercial product of a major Japanese confectionery company, was used as a control.

Results and Discussion

1. Effect of defatting conditions on the fat content of the pigskin samples

The results of proximate analysis of pigskin samples were compared with those of lean pork loin (Table 1). Water content of the pigskin was 43.6% ; significantly lower than that in the lean pork meat samples (71.3%). The protein content in dry matter (DM) was 57.8% that of the pigskin, which was lower than that in the lean meat (74.2% DM), but still high enough to be a viable protein source. The fat content of the pig skin was 22.9%, which was approximately four times higher than that in the lean meat (5.8%), while the ash content of the pigskin was 0.4%, one third of that in the lean meat (1.2%). It was thought that the high fat content of the pigskin is attributed mainly to subcutaneous fat, suggesting the necessity of defatting.

As shown in Fig. 1, the fat content in dry matter before defatting was 40.6% DM, and this was decreased after immersing the samples in hot water. Although time-dependent decreases were observed, defatting treatment at 80℃ was insufficient, and the fat content was 17.0% DM even after the 80-min

Table 1 Proximate composition of pigskin and lean

sample	Proximate composition* (%)			
	Moisture	Protein	Fat	Ash
Pigskin	43.6±1.4	32.6±0.8	22.9±1.0	0.4±0.0
Lean (Pork Loin)	71.3±0.4	21.3±0.1	5.8±0.1	1.2±0.0

*Means±S.D. (n = 6)

treatment. Defatting at 100℃ was more effective than that at 80℃ : the fat content was reduced to 6.7% DM after a 60 - min treatment while maintaining its shape. F urther more, when content was reduced to 5.3% DM after an 80 - min treatment, the skin became fragile, and damage was observed after the 80-min treatment. When the skin was defatted at 120℃, the fat content dropped rapidly to 11.9% DM, but earlier signs of disintegration were observed after 20 min of treatment. The skin sample was almost completely dissolved after 40 min of treatment. Based on these results, a high water temperature of 100℃ and a defatting time of 60 min were considered optimum for obtaining a good balance between defatting efficiency and general condition of the skin sample.

Table 2 shows the proximate composition of the pigskin defatted under the above conditions. Compared with the results before defatting (Table 1), water content was increased by approximately 22%, which can be attributed to water absorption during defatting in hot water, and protein content was comparable. On the other hand, fat content was significantly reduced by approximately 90%, and ash content was decreased by 75%.

2. Effect of drying conditions on the water content of the pigskin samples, and the effect of water content and puffing conditions on the expansion rate

Because of its high water content, the defatted pigskin was dried at 80℃ using a forced-air dryer. Fig. 2 shows time-dependent changes in the water content of the pigskin samples during drying and time-dependent changes of the expansion rates of the dried skin samples after puffing at 200℃, either by deep-frying in canola oil or baking in the oven. The water content was 65.7% immediately after defatting treatment, and this was decreased to 13.1% after 2 h of drying. The skin after drying for 2 h expanded significantly 22-fold after deep-frying, but only 2.6-fold after baking. When the drying time was extended to 3 h, the water content in the skin was reduced further to 4.8%, and deep-fried samples showed greater expansion (31.2-fold)

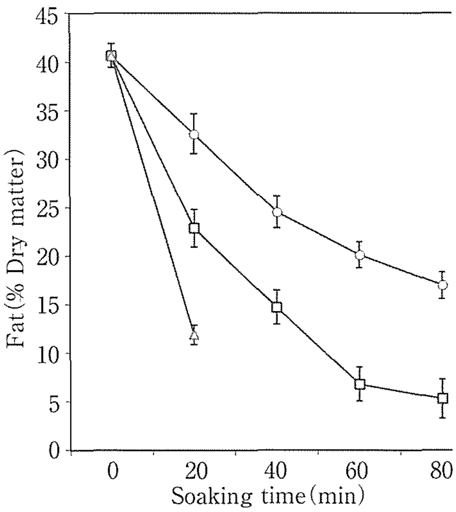

Fig. 1 Effect of deffating treatment on fat content in pigskin (Means ± S.D. ; n = 6)

Pigskin samples were defatted by immersing in hot water at 80℃ (○), 100℃ (□) or 120℃ (△).

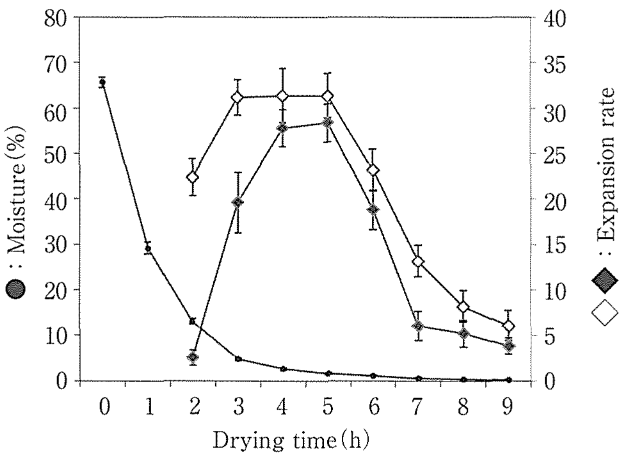

Fig. 2 Effect of drying treatment on moisture content and expansion rate of pigskin (Means ± S.D. ; n = 6)

● : Moisture, ◇ : Deep-fried pigskin, ◆ : Baked pigskin
Deffated pigskin was dried at 80℃ in forced-air dryer. Dried pigskin was puffed by deep-frying or baking at 200℃.

Table 2 Proximate composition of deffated pigskin

Moisture	Proximate composition* (%)		
	Protein	Fat	Ash
65.7 ± 1.1	31.3 ± 1.6	2.3 ± 0.5	0.1 ± 0.0

*Means ± S.D. (n = 6)
Pigskin was defatted by immersing in hot water at 100℃ for 60 min.

and baked samples showed significant expansion (19.6-fold). An additional 1 h of drying (total of 4 h drying) reduced the water content to 2.7% but did not largely change the expansion rate of the deep-fried skin samples (31.4-fold). On the other hand, the expansion rate of the baked skin samples (27.8-fold) was comparable to that of deep-frying. The water content was reduced to 1.6% after 5 h of drying, while expansion rates were almost unchanged after 4 h of drying. The water content was decreased to 1.1% after 6 h of drying, and the expansion rate subsequently declined as the water content dropped.

Vaporization of water in the tissue during puffing was thought to influence the expansion rate of the pigskin. It was considered that generation of insufficient energy during vaporization and an excessively low water content while hardening of the surface layer before full vaporization of water with an excessively high water content accounted for poor expansion. Thus, it was demonstrated that retaining the water content of the pigskin at around 2% after the drying process is necessary to obtain sufficient expansion by baking. The pigskin tissue became fragile after defatting in hot water, and this fragility appeared to contribute to good expansion. The expansion rate was higher in the deep-fried pigskin than in the baked pigskin. This can be explained by faster vaporization by deep-frying than by baking, attributed to the higher heat capacity in liquid than in gas. Indeed, the puffing process was completed in around 10 s when the pigskin was deep-fried, but in 2 min when baked. In addition, when the drying temperature was raised above 90℃, the water in the pigskin rapidly dissipated, the surface layer was burnt and hardened, and good puffing was not observed (data not shown). Based on these results, a drying temperature of 80℃ w as considered optimum for obtaining an acceptable dry state of the pigskin. Taken together, results revealed that drying the defatted pigskin at 80℃ for 4～5 h is necessary to preserve the pre-puffing water content at around 2% to obtain sufficient expansion by baking.

3. Tissue observation before and after puffing treatment

The pigskin samples were dried at 80℃ for 4 h to achieve good expansion rates, and external appearance (Fig. 3) and tissue morphology (Fig. 4) before and after puffing treatment were examined. The area rich in collagen fibers, most likely to be the dermis[14),15)], was tightly packed and had no voids before puffing treatment. On the other hand, regardless of the puffing procedure (deep-frying or

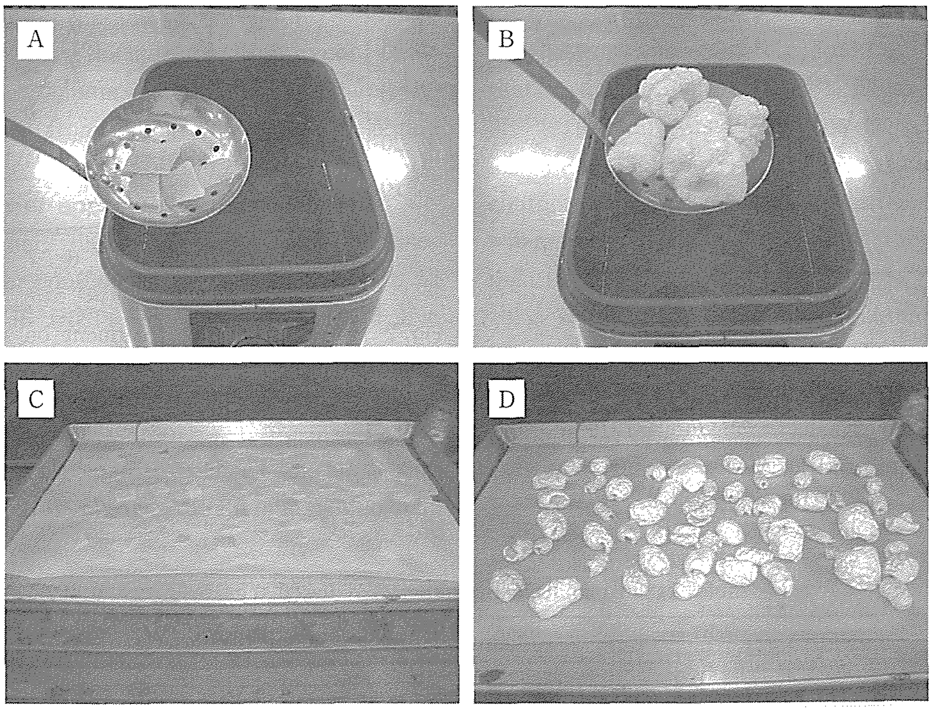

Fig. 3 Appearance of pigskin before and after puffing treatment

A : Before deep-frying treatment, B : After deep-frying treatment
C : Before baking treatment, D : After baking treatment

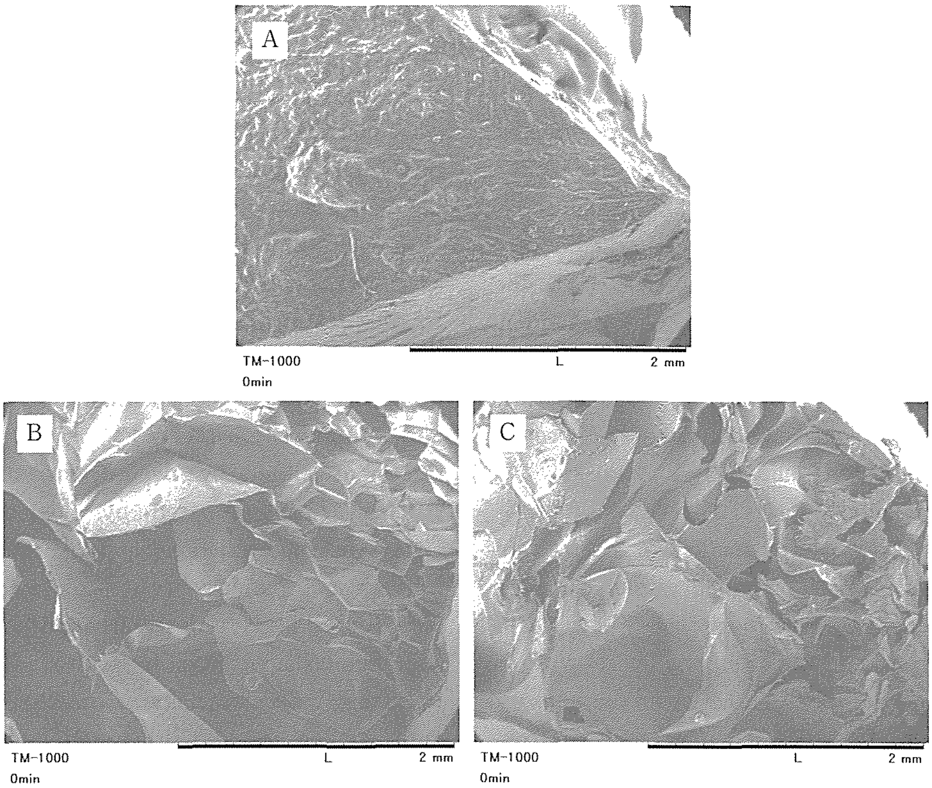

Fig. 4 Microscope views of tissue morphology of pigskin before and after puffing treatment

A : Before treatment, B : After deep-frying treatment, C : After baking treatment, Black bar indicate 2mm.

baking), many voids were observed in the corresponding area after puffing treatment as the skin expanded outward, thereby curling towards the subcutis. The size of the voids was slightly larger in the deep-fried skin than in the baked skin and can possibly be attributed to the rapid vaporization mentioned above, suggesting that the differences in void size account for differences in expansion rates.

4. Proximate composition and collagen content in puffed pigskin

The defatted pigskin samples were dried at 80℃ for 4 h, puffed by either deep-frying or baking, and then subjected to analysis to determine proximate composition and collagen content. As shown in Table 3, protein and collagen content in the deep-fried pigskin was 60.4% and 46.1%, respectively. Fat content was also high (36.7%), possibly due to residual oil used for deep-frying. Baking the skin, instead of deep-frying, significantly reduced the fat content to 4.4%, which was one-eighth the level of the deep-fried skin. As the fat content decreased, the baked skin became very rich in protein (94.5%) and collagen (75.7%). There was no difference in the ash content between the deep-fried skin and the baked skin.

On the other hand, the water content was slightly higher in the deep-fried pigskin (2.5%) than in the baked pigskin (1.1%). The rapid vaporization that occurred during deep-frying was particularly active on the surface of the skin. This can possibly

Table 3 Proximate composition of puffed pigskin

Product	Proximate composition* (%)				
	Moisture	Protein	Fat	Ash	Collagen
Deep-fried pigskin	2.5 ± 0.2^{a}	60.4 ± 1.3^{b}	36.7 ± 1.3^{a}	0.1 ± 0.0^{a}	46.1 ± 1.8^{b}
Baked pigskin	1.1 ± 0.3^{b}	94.0 ± 1.7^{a}	4.4 ± 1.3^{b}	0.1 ± 0.0^{a}	75.7 ± 1.7^{a}

*Means ± S.D. (n = 6)
Means with different superscripts within a column are significantly different ($p < 0.01$)

be attributed to the hardening of the skin surface, which served as a seal, thereby preventing water from escaping. The carbohydrate content of 0.3～0.4% was thought to be from mucopolysaccharides, such as hyaluronic acid[16]. The energy value of the puffed skin samples was obtained by adding the energy values of individual contents, which were calculated by multiplying quantity by the corresponding energy conversion factor[17]. The energy value of the deep-fried pigskin was 573 kcal/100 g, while that of the baked skin was 417 kcal/100 g, indicating the baked skin to be a high-protein and low-calorie food.

5. Sensory evaluation

The results of sensory evaluation are shown in Table 4. The mean scores of puffed pigskin samples, regardless of whether they were made by deep-frying or baking, scored satisfactory. There was no significant difference ($p>0.01$) between the sensory properties of puffed pigskin samples and controls. More precisely, the mean score for appearance and color of puffed pigskin samples was at least +2, and that for aroma, texture, taste, and overall impression was close to +1, suggesting that puffed pigskin has the potential to be an acceptable food. For all sensory properties, the score for baked skin was higher than that for deep-fried skin, although there was no significant difference ($p>0.01$) between them. Those who evaluated the sensory properties of puffed pigskin found that the baked skin was pleasantly aromatic, crispy, and fast disintegrating, but was difficult to clear from the mouth after mastication. Unlike existing puffed snack foods, which are made primarily from grains and potatoes and are therefore rich in carbohydrate, pork-based snacks leave small pieces in the mouth when consumed. This suggests that the unpleasantness associated with its main ingredient, puffed pigskin, is likely to be attributed to its protein-rich nature. However, considering that no beverages were consumed during sensory evaluation, small pieces of the puffed pigskin remaining in the mouth would not be a serious problem, since they would be cleared when consuming a beverage under normal circumstances.

This study demonstrated that pigskin is sufficiently expanded by using a multistep procedure comprising hot-water immersion to reduce fat and tissue integrity, drying, and thermal treatment either by deep-frying or baking. The puffed pigskin prepared by this method showed good sensory evaluation results. Furthermore, unlike conventional puffed snack foods made from crops, puffed pigskin is a low-carbohydrate, high-protein, and high-collagen food. It is also a low-calorie food when expanded by baking. Unlike the conventional method[10),18),19)] used to prepare puffed pigskin, which is known *cab moo* in Thailand, *chicharron* in The Philippines, and *torresmo* in Brazil, our method does not involve low-temperature frying to reduce tissue integrity, and thus markedly reduces oil waste. In particular, making puffed skin by baking also eliminates the high-temperature frying step, and consequently produces no oil waste. Our findings suggest a means of increasing the utility of pigskin as an edible substance in an environmentally friendly manner.

Table 4 Sensory evaluation of puffed pigskin

Item	Score*		
	Deep-fried pigskin	Baked pigskin	Control**
Appearance	2.10±0.97	2.19±0.73	2.23±0.53
Color	2.05±0.90	2.19±0.66	2.10±0.61
Aroma	1.66±0.84	1.90±0.61	2.00±0.69
Texture	1.76±0.97	1.95±0.95	1.95±0.65
Taste	1.67±1.08	1.76±0.81	1.90±0.68
Overall	1.86±0.99	1.95±0.49	2.05±0.49

*Means±S.D. (n=21)
**A puffed corn snack (Product of a Japan's major confectionery company)
Means within a row are not significantly different ($p>0.01$)

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豚皮を用いた膨化食品の開発とその品質について

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畜産副産物である豚皮を有効利用するため，膨化したスナック様食品へ加工する方法の開発を試みた。その結果，脱毛した豚皮を100℃の熱水に60分間浸漬することにより皮の形状を保持したまま脱脂と豚皮組織の脆弱化を図ることができた。脱脂後の豚皮は80℃で4時間通風乾燥し，水分を約2％まで減少させた後，200℃でフライヤーを用いて油揚あるいはパン用オーブンを用いて焙焼することにより顕著に膨化した。膨化した豚皮は従来の農産物を主原料としたスナック類とは異なり，タンパク質が多くコラーゲンを豊富に含み，さらに焙焼したものは低脂肪でカロリーが抑えられていた。官能評価は油揚あるいは焙焼で膨化した豚皮のいずれも良好であった。本結果から，これまで低未利用状態にあった豚皮を有効利用した新規な食品を，食品添加物を用いずに一般的な食品加工装置で製造できることが明らかになった。

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