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VALUE ADDITION TO BROKENS OF RICE AND PULSE INDUSTRIES THROUGH PREPARATION OF RICE ANALOGUES

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Abstract: The bi–products of rice and pulse industries were utilised for development of rice analogues as value added products. Analogues rice was produced by converting the broken rice and pigeonpea dhal into flour along with water and sodium alginate as binding agent in the cold extrusion process. The analogue rice resembling the raw rice were extruded by varying two process variables viz., broken pigeonpea dhal flour (BPDF) (20, 30 and 40%) and moisture content (25, 30 and 35%). The optimisation was carried out for arriving at the combinations for composite flour for producing the rice analogues resembling raw rice enriched with protein content using design expert software. The optimisation process established highest desirability of 0.855 for 30% BPDF and 30% moisture content. The optimum combination had highest crude protein, carbohydrate, ash contents of 12.73, 71.72 and 0.990%, respectively. The colour values L*, a* and b* were found to be 69.30, 4.62 and 26.31, respectively. The pasting temperature and peak viscosity were 77.65°C and 23173.3 cP.
Keywords: broken rice and dhal utilisation, rice analogue, extruded rice, rice like grains

1. INTRODUCTION

Rice is one of the leading food crops and sustains two–third of the world's population, providing 20% of the world's dietary energy supply (*Choi et al. 2010*) and staple food for 2.5 billion people (*Khan et al. 2009*). The slogan "Rice is Life" can be considered appropriate for India as this crop plays a vital role in our national food security and is a means of livelihood for millions of rural households (*Deshwal et al. 2019*). Rice is a rich source of macro and micronutrients in its unmilled form (*Steiger et al. 2014*) but milling is an important criteria for obtaining whole rice kernel. An issue of concern is breakage of kernels during milling (30–50% Patel et al. 2001) and removal of micronutrient–rich bran layers. The broken grains are mainly used as a feed or brewing raw materials, which has a low economic value (*Mishra et al. 2012*). However, there is considerable potential for value addition of this relatively cheaper by–product of the rice milling industry. This would not only supplement nutrition for a large part of the population but could also help in the conservation of food and additional monetary benefit to the rice milling industry (*Steiger et al. 2014*).

Pulses are another important global food crops providing much–needed protein to the carbohydrate–rich vegetarian diet (*Yadav et al. 2019*). It is therefore popularly known as "Poor man's meat", contributing significantly to the nutritional security of the country (*Singh et al. 2015*). Pigeonpea (Cajanas cajan) is an important pulse crop in India followed by gram contributing 15 to 20% in the total production. Pigeonpea is consumed in the form of dehusked split pulse known as dhal. Processing of pulses into dhal is being coupled with losses and wastage estimated to be about 10–25% (*Singh, 1995*). Utilising these milling by–products would supplement nutrition to a large part of the population and economic benefit to the pulse milling industry.

Despite being a primary food, rice is low in protein and high in starch. The low protein levels in rice cause deficiencies of protein and some essential amino acids in people who take it as their primary diet. One approach to overcome the problems is to produce "faux" rice kernels using milling by–products of rice and dhal mills by extrusion technology (*Dexter 1998*). Based on the above facts the investigation was undertaken to standardize the composite flour for the production of rice analogues using by–products of rice and dhal mills by extrusion processing and analyze the quality parameters.

2. MATERIALS AND METHODS

— Raw materials

The raw material used for the study *viz.*, whole rice grains and broken rice (BPT 5204) were procured from M/s. Radhe Agro Industries, Raichur and broken pigeonpea dhal (TS–3R) were procured from M/s. Raghavendra Pulses, Kalaburagi. The brokens were ground using hammer mill and then sieved manually by using 150 µ sieve to obtain flour of uniform particle size (*Patel et al. 2001*). The broken rice flour is represented as BRF and broken pigeonpea dhal flour as BPDF in the paper.

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— Physical properties of whole rice kernels

The engineering properties *viz*., size, true density, bulk density and thousand grain weight of whole rice kernels were measured using standard procedures and instruments explained by Mohsenin (1986).

— Extrusion of rice analogues

Cold extruder (La Monferrina, Dolly mini, Italy) was used for development of rice analogues. The unit is basically a single screw extruder consists of a stainless steel screw having 3:1 barrel length to diameter ratio with uniform pitch. It was powered by a 2.25 kW electrical motor through a speed reduction system. For preparation of the rice analogues with desirable internal and apparent good texture, the blended broken rice flour, dhal flour and binding agent were tempered by adding a predetermined amount of water (25–35%) by spraying and mixing for 30 min for equilibrium (*Yogeshwari et al. 2019*). The operating conditions were fixed at 55 rpm screw speed and 1.5 kg/h feed rate. The temperature profile in the barrel zone towards rice shaped die was 60°C. After obtaining the dough of required consistency, extruder was operated to produce the rice analogues with desired size using cutter blade attached at the outlet of the die. The extrudates were collected, cooled at room temperature and dried overnight in tray drier at 40°C before packing.

— Fabrication of die for extrusion of rice analogues

The cold extruder die having the external dimensions of 59.00 mm diameter and 20 mm thickness was fabricated to fit in the existing cold extruder machine. Based on the physical properties of the rice grains, the size of elliptical shaped die holes resembling the rice like kernel was finalized. The average kernel dimensions obtained from the section 3.1 (5.330 mm length, 1.799 mm width and 1.455 mm thickness) were used and the die hole dimensions selected for fabrication were 6.0 mm length and 2.0 mm width (at the centre) as shown in Figure 1. The die hole dimensions selected were larger than the average size of the rice grain considering the reduction in the size due to shrinkage after drying.

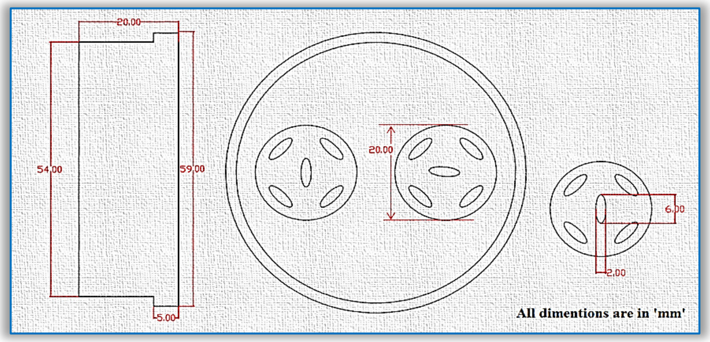

Figure 1 – Schematic diagram of cold extruder die and die hole

— Composite flour formulation for development of rice analogue

The process flow chart for the production of extruded rice analogues is presented in Figure 2. The process mainly involved the optimization of composite flour containing appropriate proportion of BPDF, BRF and water. The BPDF at different levels viz., 20, 30 and 40 per cent were blended with remaining proportion of base material BRF to bring the mixture to 100 per cent. The moisture content of composite flour was achieved by adding the water at 26.7, 35.7 and 46.2 ml/100g to obtain moisture content of 25, 30 and 35 per cent considering the initial moisture of the flour as 5%. Sodium alginate at 1% (*Cox and Cox 1993*) was added as binding agent to provide cohesive powder mixture forming rice analogues due to the poor binding ability of rice flour (*Pagani 1986; Patel et al. 2001*). Mixing of the flour was continued until the mixture was homogeneous (approx. 10 min) and the dough was rested for 2 hours before putting it into the extruder (*Budi et al. 2015*). The rice analogues were

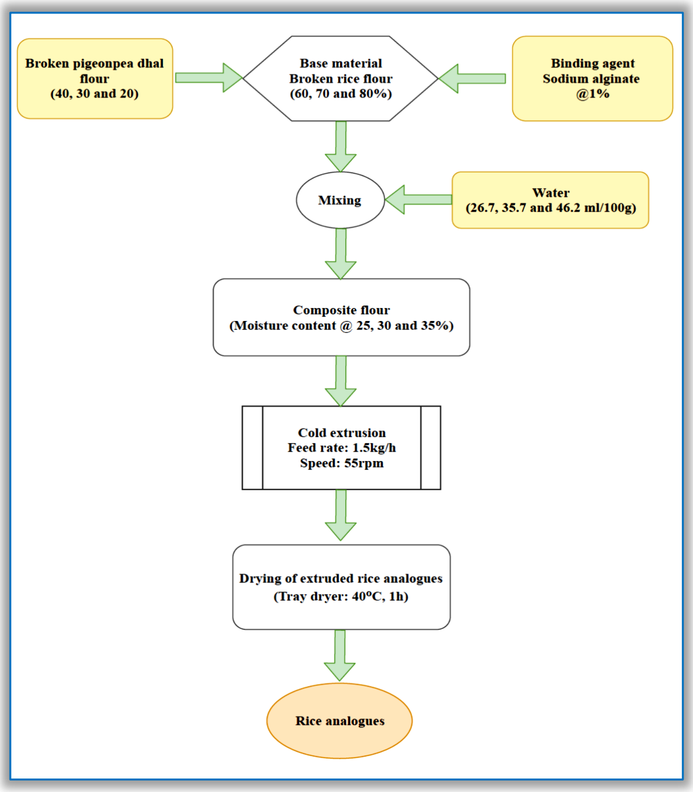

Figure 2 – Process flow chart for development of rice analogues

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extruded in a cold extruder with cutter blade. After reaching a steady operating state and producing good extrudate (uniform), the product was dried to moisture content not more than 15 per cent on wet basis (Steiger 2010) using a tray drier at 40°C for 1 h (*Patel et al.* 2001).

— Experimental Design

The experiments were designed according to the general factorial design. The numerical optimization was carried out using Design Expert software 7.7.0 (Statease Inc., Minneapolis, USA) for two independent variables of extrusion flour mix viz., BPDF and moisture content at three levels each as shown in Table 1. The dependent variables/responses selected for optimization process were the quality characteristics viz., crude protein, carbohydrate, ash and colour values.

Table 1. Treatment combinations for standardization of composite flour

Treatments	Broken rice flour (%)	Pigeonpea dhal flour (%)	Moisture content (%)
T_0	100	0	(Avg. values of 25, 30 and 35%)
T_1	80	20	25
T_2	80	20	30
T_3	80	20	35
T_4	70	30	25
T_5	70	30	30
T_6	70	30	35
T_7	60	40	25
T_8	60	40	30
T_9	60	40	35

T_0 – Dhal–0%, M.C–Avg. of 25, 30 and 35%, T_1 – Dhal–20%, M.C–25%; T_2 – Dhal–20%, M.C–30%; T_3 – Dhal–20%, M.C–35%; T_4 – Dhal–30%, M.C–25%; T_5 – Dhal–30%, M.C–30% ; T_6 – Dhal–30%, M.C–35%; T_7 – Dhal–40%, M.C–25%; T_8 – Dhal–40%, M.C–30%; T_9 – Dhal–40%, M.C–35%.

— Quality characteristics of extruded rice analogues

The selected proximate characteristics were determined for the developed rice analogs with different treatment combinations. The crude protein, carbohydrate and total ash content were analysed by the AOAC (2005) and the colour values (L^*, a^* and b^*) were determined by Hunter's Lab Colorimeter (*Hunterlab, CLFX–45, Reston, USA*). The pasting properties of rice analogues were determined by a modular compact rheometer (Anton–Paar GmbH, MCR 102, Graz, Austria) as per the procedure explained by Kim et al. (2009).

— Economics of production of rice analogues

The significant part of rice analogues development depends not only on their legal status, expected bioavailability, stability and sensory acceptability but also on the cost effectiveness. The cost of production for rice analogues was calculated using two importance cost concepts viz., fixed costs and variable costs.

3. RESULTS AND DISCUSSION

— Physical properties of rice kernels

The physical properties viz., size, bulk density, true density and 1000 grain weight were analysed. The average values of length width and thickness of the rice grains were found to be 5.33±0.04 mm, 1.79±0.0 mm and 1.45±0.01 mm, respectively and were similar to that reported earlier (L–6.61mm, W–1.75mm and T–1.40mm) by Ghadge and Prasad (2012). The average 1000 grain weight was 9.64±0.048 g. The weight of the rice grain was very less due to smaller and fine kernel size after polishing. The bulk density and the true density values were recorded to be 869.60±38.35 kg/m^3 and 1397±46.12 kg/m^3, respectively. The results are in close agreement with the results recorded for bulk density of different varieties of rice by Singh et al. (2005) varied between 770–880 kg/m^3 and true density (1269.1 kg/m^3) of rough rice by Varnamkhasti et al. (2008).

— Development of fortified rice analogues using broken rice and pigeonpea dhal

Rice analogues were produced by the process of extrusion using laboratory scale cold extruder. The extruded rice analogues developed using different treatment combinations of moisture content and pigeonpea dhal flours is shown in Plate 9. The process mainly involved the formulation of appropriate flour mix of broken rice, broken pigeonpea dhal, binding agent and moisture content as per the treatment combinations. The flour mixture was then extruded in a cold extruder through rice shaped die and dried to a moisture content of not more than 15% on wet basis.

— Effect of BPDF and moisture content on chemical properties of rice analogues

The important components of proximate composition which have the major effect on the optimisation of composite flour viz., crude protein, carbohydrate, ash and colour values for different treatment combinations of extruded rice analogues were estimated and are shown in Table 2.

— Crude protein

The addition of pigeonpea flour was focused on utilizing the brokens and enhancing protein content of analogue rice. The result presented in Table showed significantly higher protein in the extruded rice analogues with BPDF (10.84±0.06 to 13.47±0.07%) per cent as compared to raw rice (8.51±0.05%) and rice analogue without BPDF (8.37±0.32%). It was observed that, the crude protein content of the rice analogues increased with increase in pigeonpea level and moisture content. The high protein content of pigeonpea flour (20.893±0.58%) contributed in increasing the protein content of extruded rice analogues and in–situ development of temperature might have destructed the protein levels resulting in lower levels of protein in low moisture extrusion. The results reported by Patel et al. (2001) for protein (11.63%) content of rice analogues produced by broken rice and blackgram and Khairunnisa et al. (2017) for production of high protein (11.34%) rice analogues by incorporation of soybean flour were in agreement with the results.

Table 2. Proximate composition and colour values of extruded rice analogues

Treatments	Proximate composition and colour values of extruded rice analogues					
	Crude protein (%)	Carbohydrate (%)	Ash (%)	L* value	a* value	b* value
T_R	8.51±0.05	78.05±0.31	0.52±0.02	93.69±0.00	0.08±0.03	5.54±0.06
T_0	8.37±0.32	78.42±0.62	0.50±0.01	86.50±1.88	1.65±0.26	10.48±0.67
T_1	10.84±0.06	74.65±0.24	0.58±0.01	67.51±0.20	4.34±0.09	26.25±0.15
T_2	11.00±0.02	73.97±1.48	0.63±0.01	69.01±0.31	3.74±0.05	25.70±0.57
T_3	11.08±0.04	73.00±0.57	0.65±0.03	72.89±0.60	3.54±0.07	24.09±0.73
T_4	12.38±0.02	72.76±1.27	0.97±0.03	66.17±1.37	4.78±0.32	27.18±0.59
T_5	12.70±0.03	71.72±0.82	0.99±0.02	68.30±0.76	4.62±0.10	25.91±0.22
T_6	12.71±0.02	70.84±0.61	1.01±0.01	70.87±0.79	4.56±0.19	26.30±0.40
T_7	13.02±0.01	70.24±0.31	1.06±0.02	64.58±0.78	5.07±0.33	28.73±0.58
T_8	13.43±0.31	70.04±0.19	1.12±0.00	66.12±1.16	4.95±0.29	27.66±0.54
T_9	13.47±0.07	69.54±0.53	1.18±0.02	69.17±1.28	4.80±0.15	27.22±0.61
CD@1%	0.417	2.208	0.066	2.921	0.610	1.527
SE(m) ±	0.141	0.748	0.022	0.990	0.207	0.517
CV	2.112	1.775	4.589	2.372	9.349	3.863
Significance	S	S	S	S	S	S

*S– Significant, NS– Non significant. T_R– Raw rice (Control), T_0– Dhal–0%, M.C–Avg. of 25, 30 and 35%, T_1– Dhal–20%, M.C–25%; T_2– Dhal–20%, M.C–30%; T_3– Dhal–20%, M.C–35%; T_4– Dhal–30%, M.C–25%; T_5– Dhal–30%, M.C–30% ; T_6– Dhal–30%, M.C–35%; T_7– Dhal–40%, M.C–25%; T_8– Dhal–40%, M.C–30%; T_9– Dhal–40%, M.C–35%.

— Carbohydrate

The results of carbohydrate content in the extruded rice analogues showed the values ranging from 69.54±0.53 to 74.65±0.23 per cent as compared to 78.05±0.31 per cent in raw rice and rice analogue without BPDF 78.42±0.62 per cent. The carbohydrate content of rice analogues decreased with the increase in BPDF and moisture content and might be due to increase in the protein contributed from BPDF. Similar results of carbohydrate contents of 71.94% were reported by Sumardiono et al. (2014) for production of rice analogues using composite flour and Khairunnisa et al. (2017) for production of high protein rice analogues by incorporation of 30% soybean flour (75.65±0.31%).

— Total ash

Ash content represents the total of minerals in the extruded rice analogue. The ash content was ranging from 0.58±0.01 to 1.18±0.02 % compared to raw rice (0.52±0.02%) and rice analogue without BPDF (0.50±0.01%). It was observed that, with an increase in the amount of pigeonpea flour, the ash content of the blends increased significantly. The increase in the ash content was probably due to the addition of pigeonpea flour (4.188±0.25) which had higher amount of ash content (*Kaushal et al. 2012*). While, increase due to increase in moisture content might be attributed to the addition of minerals through process moisture during extrusion and also from the extruder barrel (*Singh et al. 2000*). Similar results were reported by Khairunnisa et al. (2017) while producing high protein rice analogues by incorporation of soybean flour (1.40±0.03%).

— Colour (L*, a* and b*)

The colour values were significant among all the treatments. L* (whiteness) value ranged from 64.58±0.78 to 72.89±0.60 compared to raw rice (93.69±0.00) and rice analogue without BPDF (86.50±1.88). It was observed that, the value of whiteness (L*) decreased with the increase of BPDF lead to dark colored rice analogue might be attributed to the composition of the flour and colored pigments of the flours, which in turn depends on the botanical origin of the plant (Aboubakar et al. 2008). Whereas, the L* decreased with the decrease in the moisture content due to higher temperature generation during the process of extrusion.

The a* (redness) value was recorded to be ranged from 3.54±0.07 to 5.07±0.33 for rice analogues and for raw rice and rice analogue without BPDF were 0.08±0.03 and 1.65±0.26, respectively. The values of b* (yellowness) for extruded rice analogues ranged from 24.09±0.73 to 28.73±0.58 whereas, raw rice and rice analogue without BPDF were 5.54±0.06 and 10.48±0.67, respectively. The redness (a*) and yellowness

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(b*) increased with increase in BPDF and decreased with increase in moisture. The increased a* and b* was due to colored pigments of BPDF based on botanical origin (Aboubakar et al. 2008) and the development of non–enzymatic browning of carbohydrates. Similar results were reported by Khairunnisa et al. (2017) for production of high protein rice analogues by incorporation of soybean flour decreased the L* (67.22 to 57.68) increased the a* (1.63 to 2.22) and b* (11.98 to 13.42) values.

— Pasting properties of extruded rice analogues

The important pasting properties viz., peak viscosity and pasting temperature were determined and data on mean values are summarized in Table. 3.

Peak viscosity (PV) is the rapid increase in viscosity when sufficient number of sample granules becomes swollen. All the flours showed a gradual increase in viscosity with increase in the temperature. The peak viscosity ranged from 22350±132.8 to 24678±146.2 cP compared to the raw rice (31340±240.9 cP) and rice analogue without BPDF (29752±689.4 cP). The peak viscosity decreased with increase in BPDF and moisture content. Pasting temperature (PT) is another important component of pasting property indicating the minimum temperature required to cook the flour. The PT was observed to be ranging from 79.46±0.18°C to 77.29±0.08°C as compared to raw rice (76.43±0.17°C) and rice analogue without BPDF (77.09±0.50°C). The PT increased with increase in pigeonpea dhal flour. The changes in the pasting properties could be attributed to the swelling power of pigeonpea containing protein as high protein and starch content in the flours might cause the starch granules to be embedded within a stiff protein matrix which limits the access of the starch to moisture and restricts the swelling (*Kaushal et al.* 2012).

Table 3. Pasting properties of extruded rice analogues

Treatments	Peak viscosity (cP)	Pasting temperature (°C)
T_R	31340±240.9	76.43±0.17
T_0	29752±689.4	77.09±0.50
T_1	24678±146.2	77.29±0.08
T_2	24444±197.5	77.65±0.26
T_3	24310±292.6	77.79±0.26
T_4	23373±191.6	78.34±0.25
T_5	23173±153.7	78.68±0.34
T_6	23120±100.6	78.94±0.49
T_7	22673±172.4	79.09±0.18
T_8	22623±213.2	79.30±0.19
T_9	22350±132.8	79.46±0.18
CD@1%	816.8	0.927
SE(m) ±	276.7	0.314
C.V.	1.940	0.696
Significance	S	S

*S– Significant. T_R – Raw rice (Control), T_0 – Dhal–0%, M.C–Avg. of 25, 30 and 35%, T_1 – Dhal–20%, M.C–25%; T_2 – Dhal–20%, M.C–30%; T_3 – Dhal–20%, M.C–35%; T_4 – Dhal–30%, M.C–25%; T_5 – Dhal–30%, M.C–30% ; T_6 – Dhal–30%, M.C–35%; T_7 – Dhal–40%, M.C–25%; T_8 – Dhal–40%, M.C–30%; T_9 – Dhal–40%, M.C–35%

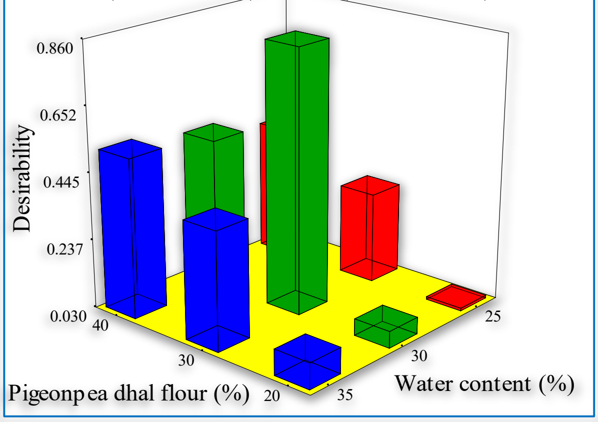

Figure 3 – Desirability graph for combinations of BPDF and moisture content for development of rice analogues

— Optimisation of BPDF and moisture content for production of extruded rice analogues

Numerical optimization was applied to determine the optimal flour composition containing BPDF and moisture content for production of rice analogues. Optimum points established 9 solutions, but only several points were chosen as optimum points, on condition that it satisfied the criteria mentioned. The optimimum desirability of 0.855 was obtained for flour composition having 30 per cent BPDF and 30 per cent moisture content for production of rice analogues as depicted in Figure 3.

— Economics of rice analogues production

The cost involved in production of rice analogue was found to be Rs. 41.0 per kg. The production seems to be costly whereas, increase in the cost can be mitigated by adding the nutrients in the rice analogues and mixing with raw rice @ 1:50 ratio. The fortification process involves simple operations and minimum additional investment is needed in particularly rice consuming states as a whole to accomplish fortification to combat the malnutrition. Given the present technology, a set of equipments for blending fortified rice analogues with raw rice could be accomplished easily in any rice mill.

4. CONCLUSION

The rice analogues were developed utilising the broken rice and broken pigeonpea dhal flours along with water and binding agent in an extruder. The laboratory model cold extruder could be used to produce rice analogues resembling the rice kernels with similar physico–chemical properties. The process optimisation was carried out for optimum combination of the broken pigeonpea dhal flour and moisture with the broken

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rice flour as base material. Addition of pigeonpea dhal flour in the extruded rice analogue flour mix contributed to the increased protein and ash contents along with decreased peak viscosity and increased pasting temperature. The rice analogue production technology can be utilized for fortification process involving simple operations and minimum additional investment needed in particularly rice consuming states as a whole to accomplish fortification to combat the malnutrition.

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