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Evaluation of Meat and Egg Traits of Beijing-you Chickens Rotationally Grazing on Chicory Pasture in a Chestnut Forest

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Keywords

Beijing-you chickens, chicory, rotational grazing, meat and egg traits, poultry agroforestry system.

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ABSTRACT

Barn and cage-fed chickens have presented several problems, such as high rates of infectious disease and consequent antibiotic abuse, poorer chicken health and welfare, and often poorer meat and egg quality compared with free-range chickens. The poultry agroforestry system is becoming increasingly popular in many poultry farms nowadays. In this study, to evaluate the contribution of poultry agroforestry system to enhance some meat and egg traits of Beijing-you chickens, some indexes of meat and egg qualities, some indexes of slaughter traits, and the feed conversion efficiency were investigated in rotational grazing Beijing-you chickens on chicory (*Cichorium intybus* L.) pasture (CGRG group) and only free-ranging chickens on bare land without forage (control group) in chestnut forest. Results showed that the live body weight, the dressing weight, the thigh muscle weight, and the breast muscle weight were increased ($p<0.05$) based on the decrease of 15% feed concentration in the CGRG group relative to the control. Furthermore, compared with the control, the crude ash, the essential amino acid content, and the inosinic acid content were increased ($p<0.05$), and the crude fat contents were decreased ($p<0.05$) in the thigh and breast muscles, while the yolk cholesterol and the feed conversion ratio were significantly decreased ($p<0.05$) in the CGRG group. This study would provide a scientific basis and technological support for the large-scale demonstration and application of rotational grazing chickens on the artificial pasture in forest.

INTRODUCTION

The health and welfare problems of barn and caged-feeding chickens have caused concern within the booming poultry industry, particularly environmental and animal welfare concerns (Yates *et al.,* 2007; Geng *et al.,* 2007). The restrictive surroundings of the caged-feeding chickens have many negative influences, such as increased rates infectious diseases with consequent antibiotic abuse, environmental pollution, lower meat and egg quality, and poor animal welfare (Charles & Walker, 2002; Geng *et al.,* 2007). At the same time, there are increasing concerns with food safety, and good quality poultry meat and egg products are favored by consumers.

The reasonable development and utilization of a large area of forest land, as well as the establishment of optimized developing models in forests, have become a focus for economic development. The poultry agroforestry system has been applied in Northern Europe and China as they may offer benefits including: improved welfare, reduced feed costs, and payback periods for forests (Hemery, 2005; Yates *et al.,* 2007).

According to previous results, inter-planting suitable forage species and rearing free-range chickens in forests is an important and effective model for the development of the poultry agroforestry system (Yates *et al.,* 2007; Guo *et al.,* 2008; Jiang *et al.,* 2008a,b; Chen *et al.,* 2010; Meng *et al.,* 2012; Mao *et al.,* 2015). The following specific reasons for such system, i.e., improving the welfare conditions of outdoor poultry using the tree cover, providing fresh forage for 'forest-reared' poultry, and producing high quality meat and egg products, were emphasized in particular (Meng *et al.,* 2012; Mao *et al.,* 2015). Lingnan yellow feather broilers reared on alfalfa pasture in a forest of *Cinnamomum camphora* presented excellent slaughter performance and meat qualities, and their lipid metabolism was well-regulated (Jiang *et al.,* 2008b). Meng *et al.* (2012) reported that Beijing-you chickens rotationally reared at a density of 2250 heads/hm^2 on a mixed pasture (*Amaranthus hypochondriacus* and *Sorghum bicolor*×*S. sudanense*, seed sowing rate = 1:1) in a chestnut orchard presented significantly higher total amino acid, essential amino acid, crude protein, and inosinic acid contents in thigh and breast muscles, as well as 13.1% and 3.3% higher live body weight and dressing percentage, respectively, compared with those reared in the same orchard with no forage planted. The muscle triglyceride and cholesterol contents of broiler chickens grazing on a pasture of *Chamaecrista rotundifolia* in loquat orchard were significantly decreased compared with those reared in cages (Chen *et al.,* 2010).

The Beijing-you is a good local chicken variety. Today, more than one million Beijing-you chickens are reared and sold annually in Beijing, but are often reared using barn- and caged-feeding methods, which has many negative effects, such as high rates of infectious diseases with consequent antibiotic abuse, poor meat and egg qualities, and poor animal welfare (Geng *et al.,* 2007).

Chicory (*Cichorium intybus* L.) is a perennial herb that may potentially be complementary to more traditional forage crops for grazing chickens and cows due to its favorable traits, i.e. it is deep-rooted, drought resistant, and has a high protein and mineral content (Foster, 1988). It also has a high content of uronic acid (80-90 g/kg DM), out of which approximately 80% is soluble. Chicory is very interesting as potential fiber sources in cereal-based diets for weaned piglets due to its high uronic acid content and has only a minor negative impact on the total tract digestibility (Ivarsson *et al.,* 2010).

The present study was conducted to evaluate the meat and egg qualities, slaughter traits, and the feed conversion ratio of Beijing-you chickens rotationally grazing on the chicory pasture in a chestnut forest in Beijing, and to provide the scientific basis and technological support for the large-scale demonstration and application of rotational grazing chickens on an artificial pasture in forest.

MATERIALS AND METHODS

The experiment was carried out at the open forest of Beijing Ainong Breeding Chicken Base (Lat. 40°36′ N, Long. 117°06′ E), located at Gaoling town, Miyun county, about 150 km far from Beijing, from April to October, 2013. The canopy density of chestnut forest is about 0.18, with row spacing and line spacing of about 5 m × 8 m.

The seeds of chicory (*C. intybus* L.), with about 98% germination rate, were provided by the Beijing Clover Group in China. The chicory pasture was established at 20 cm sowing line and 18 kg/hm^2 actual sowing rate at the end of April, 2013.

In total, 270 Beijing-you chickens, with 523.88 g average live body weight and eight weeks of age at the beginning of the experiment, were allotted to two different treatments. In treatment 1(CGRG), 135 Beijing-you chickens rotationally grazed on chicory pasture planted in the forest area, with 667 m^2 of grazing area and at a grazing density of 2025 heads/hm^2. The grazing area was divided in two 334m^2 plots, which were grazed for three weeks each, successively. In treatment 1, birds grazed on chicory pasture, with average natural growth height of 30.5 cm, with 75% coverage, established in a chestnut forest. The forage contained about 13.90% crude protein, 8.20% crude fat, 13.90% crude fiber, 17.90% crude ash, 0.84% calcium (Ca), and 0.47% phosphorus (P). In treatment 2 (control), 135 birds grazed a 667m^2 forest area, with no forage planted, at a density of 2025 heads/hm^2.

The CGRG group received about 85% of a supplemental concentrated feed supplied to the control group. CGRG birds received 30% and 70% of the supplemental diet at 07:00-07:30 and at 18:00-18:30, respectively, where as the birds of control group were fed 50% of the supplemental diet at 07:00-07:30 and 50% at 18:00-18:30.

The concentrated feed was manufactured at Beijing Ainong Breeding Chicken Base, China, and contained 61.82% of corn, 11.96% of soybean meal, 11.96%

of wheat bran, 0.30% of salt, 1.99% of bone meal, 3.99% of cottonseed meal, 3.99% of rapeseed meal, and 3.99% of vitamin and mineral premix. The feed contained 22.02% of crude protein, 4.30% of crude fibre, 10.25% of crude fat, 11.90% of crude ash, 4.37% of Ca, and 0.14% of P.

The daily supplementation of the concentrated diet to the CGRG and control birds were gradually increased with age, as shown in Table 1. A poultry shed (density of about 10 birds/m^2) was established in each grazing plot. Each grazing plot was provided with a tube feeder (10-bird capacity) and a drinker (30-bird capacity). The experimental chickens grazed in forest pasture areas from 08:30 to 18:00, and were enclosed in the shed for the remaining time.

Table 1 – Amount of daily individual supplementary concentrated diet fed to the control and CGRG groups of Beijing-you chickens at different ages

	Age of chicken (weeks)						
Treatment	8–9	10–11	12–13	14–16	17–19	20–22	23–25
Control (g)	40.0	45.0	52.0	58.0	60.0	63.0	68.0
CGRG (g)	34.0	38.3	44.2	49.3	51.0	53.6	57.8

The experimental chickens, were fasted for at least 12 h before weighing at the beginning, middle (16 weeks old), and the end of experiment (25 weeks old) to determine average individual live body weight. At the end of experiment, 15 birds of the CGRG and control groups were randomly selected and sacrificed. Birds were plucked and the feathers were weighed. Individual hot carcass weight, eviscerated weight, thigh muscle weight, and breast muscle weight were measured using a digital precision scale. The individual fresh meat samples of the thigh and breast muscles were put into ice boxes and submitted to the laboratory, where the samples were ground and freeze-dried in a vacuum freeze dryer (Modulyod-230, USA) at -50 °C and 1.5 mbar.

Crude protein, crude fat, ash, calcium, and phosphorus contents of the thigh and breast samples were determined according to the methods of the Ministry of Health of the People's Republic of China (2011). Total amino acid and essential amino acid levels were measured using an amino-acid analyzer (Automatic Amino-acid Analyzer, L-8800, Japan). Inosinic acid content was determined by liquid chromatography (Shimadzu High-Performance Liquid Chromatography, LC-20AT, Japan), as recommended by Wang *et al.* (2011).

The following indexes were calculated, according to the following formulas.

Whole carcass yield (%) = whole carcass weight / live body weight × 100%

Empty carcass yield (%) = eviscerated carcass weight / live body weight × 100%

Leg yield (%) = thigh muscle weight / live body weight × 100%

Breast yield (%) = breast muscle weight / live body weight × 100%

Feed conversion ratio or feed to gain ratio = daily diet supply per head (g) / daily gain per head (g)

At the end of the experiment (when chickens were 25 weeks old), 20 eggs per experimental group were collected. Egg quality traits, including egg weight, albumen height, eggshell strength, egg-shape index, Haugh unit, eggshell thickness, yolk weight, yolk color, and eggshell weight, were measured according to Geng *et al.* (2011).The albumen and yolk were separated and freeze-dried in a vacuum freeze dryer (Modulyod-230, USA) at -50 °C and 1.5 mbar.

Egg chemical parameters, including albumen and yolk protein levels (by the Kjeldahl nitrogen determination method), yolk lecithin level (by the spectrophotometry), and yolk cholesterol level (by the high-performance liquid chromatography) were determined according to Geng *et al.* (2011).

The obtained data were submitted to analysis of variance, and means were compared by the least significant difference (LSD) test, using SPSS for Windows, Version 16.0 (SPSS Inc., Chicago, IL, USA). All the data were expressed as means ± SD.

RESULTS

Live body weight, whole carcass yield, andand eviscerated carcass yield of the CGRG group were 1780.32 g, 1598.86 g, and 1136.60 g, respectively, representing an increase of 238.02 g, 262.86 g and 137.30 g ($p<0.05$) compared with the control group. Feather yield was also increased significantly from 86.62% inthe control group to 89.81% inthe CGRG group ($p<0.05$). Leg and breast yields were not significantly different between the two groups ($p>0.05$). The thigh and breast muscle weights of the control group were 211.20 g and 169.80 g, respectively, and 262.10 g and 206.56 g in the CGRG group, representing increases of 24.10% and 21.65%, respectively ($p<0.05$), as shown in Table 2.

Table 2 – Effect of grazing Beijing-you chickens on chicory pasture in chestnut forest on the slaughter traits

Traits	Control	CGRG
Live body weight (g)	1542.30 ± 60.90[b]	1780.32 ± 40.23[a]
Whole carcass weight (g)	1336.00 ± 51.49[b]	1598.86 ± 36.65[a]
Whole carcass yield (%)	86.62 ± 04.00[b]	89.81 ± 02.01[a]
Eviscerated carcass weight (g)	999.30 ± 35.78[b]	1136.60 ± 23.63[a]
Empty carcass yield (%)	64.79 ± 02.98[a]	63.84 ± 01.36[a]
Thigh muscle weight (g)	211.20 ± 08.70[b]	262.10 ± 03.48[a]
Leg yield (%)	13.69 ± 00.53[a]	14.29 ± 00.28[a]
Breast muscle weight (g)	169.80 ± 06.91[b]	206.56 ± 03.86[a]
Breast yield (%)	11.01 ± 00.52[a]	11.56 ± 00.19[a]

Mean values with different superscripts in the same row indicate significant differences at p<0.05, (n = 15).

The crude protein content of the thigh and breast muscles of the CGRG group was slightly higher, but not statistically different (p>0.05) relative to the control group. On the other hand, thigh and breast crude fat contents of CGRG birds were significantly reduced (p<0.05), by 22.70% and 17.13%, respectively, relative to the control birds. Thigh and breast crude ash contents increased (p<0.05) from 5.10% and 4.87% in the control groups to 9.12% and 7.56% in CGRG group, respectively. Thigh and breast inosinic acid contents significantly (p<0.05) increased from 0.81% and 1.19% in the control group to 1.02% and 1.52% in the CGRG group, respectively (Table 3). Thigh and breast total and non-essential amino acid levels were not different between treatments (p>0.05). However, CGRG birds presented higher (p<0.05) essential amino acid levels compared with the controls, corresponding to 21.99% and 16.65% increases in the thigh and breast muscles, respectively (Table 3). It was thus clear that the daily supplementation of feed to Beijing-you chickens grazing on chicory pasture established in a chestnut forest significantly increased crude ash, inosinic acid, and essential amino acid contents, and significantly decrease crude fat content of the thigh and breast muscles.

Table 3 – Effect of grazing Beijing-you chickens on chicory pasture in chestnut forest on the thigh and breast muscle traits

	Traits	Control	CGRG
Thigh muscle	Crude protein (%)	74.25±2.41[a]	76.96±2.23[a]
	Crude fat (%)	19.87±0.86[a]	15.36±0.39[b]
	Crude ash (%)	5.10±0.21[b]	9.12±0.23[a]
	Ca (%)	4.18±0.19[a]	4.37±0.11[a]
	P (%)	0.60±0.026[b]	0.78±0.012[a]
	Inosinic acid (%)	0.81±0.052[b]	1.02±0.056[a]
	Total amino acids (%)	62.10±2.65[a]	68.16±1.67[a]
	Non-essential amino acid (%)	42.32±1.81[a]	44.08±1.21[a]
	Essential amino acid (%)	19.78±0.84[b]	24.13±0.55[a]
Breast muscle	Crude protein (%)	81.03±2.90[a]	84.67±2.23[a]
	Crude fat (%)	5.02±0.23[a]	4.16±0.13[b]
	Crude ash (%)	4.87±0.33[b]	7.56±0.16[a]
	Ca (%)	1.54±0.10[b]	2.05±0.05[a]
	P (%)	0.79±0.043[a]	0.80±0.020[a]
	Inosinic acid (%)	1.19±0.088[b]	1.52±0.035[a]
	Total amino acids (%)	70.05±3.12[a]	73.48±1.86[a]
	Non-essential amino acid (%)	45.97±2.12[a]	46.98±1.23[a]
	Essential amino acid (%)	24.08±1.15[b]	28.09±0.68[a]

Mean values with different superscripts in the same row indicate significant differences at p<0.05, (n = 15).

Egg weight, eggshell strength, albumen height, Haugh unit, yolk weight, eggshell thickness, eggshell weight, eggshape index,albumen and yolk protein content, and yolk lecithin content values were not statistically different between treatments. However, yolk color value increased from 6.50 in the control group to 8.68 in the CGRG group (p<0.05). Yolk cholesterol content decreased from 1922.15 mg/100 g (freeze-dried sample) in the controls to 1621.26 mg/100 g (freeze-dried sample) in CGRG group (p<0.05), representing 15.65% reduction (Table 4).

Table 4 – Effect of grazing Beijing-you chickens on chicory pasture in chestnut forest on the egg traits

Traits	Control	CGRG
Egg weight (g)	43.78 ±1.334[a]	44.34±1.612[a]
Eggshell strength (kg/cm^2)	4.07 ±0.154[a]	3.99±0.125[a]
Albumen height (mm)	4.81 ±0.137[a]	4.78±0.156[a]
Haugh unit	75.87 ±2.129[a]	75.86±2.656[a]
Yolk color	6.50 ±0.119[b]	8.68±0.234[a]
Yolk weight (g)	12.95 ±0.565[a]	12.89±0.523[a]
Eggshell thickness (mm)	0.42 ±0.014[a]	0.41±0.013[a]
Eggshell weight (g)	6.01±0.256[a]	5.95±0.185[a]
Egg-shape index	1.30 ±0.04[a]	1.32±0.05[a]
Albumen protein (g/100 g freeze-dried sample)	85.58 ±2.323[a]	84.70±2.735[a]
Yolk protein (g/100 g freeze-dried sample)	33.27 ±1.068[a]	33.00±0.953[a]
Yolk lecithin (g/100 g freeze-dried sample)	7.02 ±0.187[a]	6.95±0.275[a]
Yolk cholesterol (mg/100 g freeze- dried sample)	1922.15 ±50.211[a]	1621.26±45.368[b]

Mean values with different superscripts in the same row indicate significant differences at p<0.05, (n = 20).

Average daily body weight gains of the control group were 10.01 g and 6.92 g in weeks 8-16 and 17-25, respectively, but 12.16 g and 9.96 g in the CGRG chickens. Compared with the controls, the daily intake of the supplemental feed of CGRG chickens decreased (p<0.05) by 7.46 g and 9.54 g, as determined for weeks 8-16 and 17-25, respectively, corresponding to reductions of about 21.48% and 43.93%. In addition, feed conversion ratio during those periods was reduced (p<0.05) from 4.97 and 9.20 in the controls to 3.48 and 5.43 in the CGRG group, respectively, representing reductions of about 29.98% and 40.98%, respectively (Table 5).

Table 5 – Effect of grazing Beijing-you chickens on chicory pasture in chestnut forest on the feed conversion ratio

Age (weeks)	Traits	Control	CGRG
8–16	Daily supplementary concentrated diet (g)	49.78	42.32
	Daily gain (g)	10.01 ± 0.25[b]	12.16 ± 0.43[a]
	Feed conversion ratio	4.97 ± 0.14[a]	3.48 ± 0.12[b]
17–25	Daily supplementary concentrated diet (g)	63.67	54.13
	Daily gain (g)	6.92 ± 0.19[b]	9.96 ± 0.31[a]
	Feed conversion ratio	9.20 ± 0.53[a]	5.43 ± 0.28[b]

Mean values with different superscripts in the same row indicate significant differences at p<0.05, (n = 15).

DISCUSSION

Chickens reared in forest-grazing systems take full advantage of its ecological conditions, including good air, water, and soil quality, and feed freely on insects and fresh forage grasses. More importantly, such systems do not only allow free movement of chickens, improving their welfare, but also may result in excellent carcass traits. Carcass quality is used to assess both production performance and meat quality (Jiang *et al.*, 2008b; Meng *et al.,* 2012; Mao *et al.,* 2015). Jiang *et al.* (2008b) evaluated the carcass traits and the meat quality of Lingnan yellow broilers submitted to rotational grazing or free-range in natural pastures in a camphor forest, and showed that the the rotational grazing group was higher presented higher whole carcass, eviscerated carcass, and thigh yields than the free-range chickens. In another study, Meng *et al.* (2012) compared the performance of 9-wk-old Beijing-you chickens reared in a rational grazing system on a pasture of *A. hypochondriacus* and *S. bicolor* × *S. sudanense* in achestnut forest at a density of 2250 heads/hm^2 for 80 d with those reared in a free-range systems on natural pasture in the same forest. The authors obtained 13.1%, 3.3%, 8.6%, 11.3%, and 12.4% higher whole carcass, eviscerated carcass, thigh and breast yields, respectively, in the chickens submitted to rotational grazing compared with those in the free-range system. In the current study, the live body and whole carcass weights, andeviscerated carcass and feather yields of the CGRG group were 15.43%, 19.68%, 13.74% and 3.19% higher (p<0.05) than the control group. Also, CGRG birds presented 24.10% and 21.64% higher thigh and breast weights (p<0.05) than the controls. Therefore, these results show that the rotational grazing system applied had beneficial effects on body and carcass weights, carcass yield, and absolute thigh and breast muscle weights.

As reported by Liu (2011), the free amino acid, intramuscular fat, and unsaturated fatty acid levels of the muscles of Beijing-you chickens were about 6.46 g/kg of free amino acid, 10.9 g/kg of intramuscular fat, and 4.9 g/kg of unsaturated fatty acids. Amino acid content is one of the important indexes of the muscle nutritional value: the higher the values of total and essential amino acids, the higher the nutritional value (Liu & Xu, 2001; Jiang *et al.*, 2008b; Meng *et al.,* 2012). Moreover, inosinic acid content is an indicator the fresh flavor of chicken meat (Wang *et al.,* 2011). In the present study, despite the 15% reduction in the daily intake of the supplemental diet, the Beijing-you chickens under the rotational grazing system presented higher thigh and breast muscle crude ash, inosinic acid, and essential amino acid levels than those in the free-range system. Thigh and breast muscle crude ash content increased by 78.82% and 55.24% (p<0.05), inosinic acid content by 25.93% and 27.73% (p<0.05), and essential amino acid content by 21.99% and 16.65% (p<0.05), respectively, in rotational-grazing birds compared with the control group. On the other hand, the thigh and breast muscle crude protein contents of rotational-grazing birds was numerically higher (p>0.05), and crude fat contents were 22.70% and 17.13% lower (p<0.05) in rotational-grazing birds compared with the free-range birds, respectively.

Feeding plays a major role in egg quality. Gu *et al.* (2010) observed that the egg quality of free-range chickens was significantly better compared with cage-reared birds, as determined by Haugh units, yolk color, and albumen. Rhode Island Red hens grazing on the natural tropical vegetation of southern Mexico presented significantly higher egg production and eggs with darker yellow yolks than hens raised indoors (86.90% vs. 78.05% and 9.46 vs. 5.46, respectively) (Khaled *et al.,* 2013). In the current study, most of the measured egg quality parameters (egg weight, eggshell strength, albumen height, Haugh unit, yolk weight, eggshell thickness, eggshell weight, albumen protein, yolk protein, and yolk lecithin) were not different between chickens reared under the different systems (p>0.05). On the other hand,the eggs laid by the CGRG group presented darker yolks and 16.65% lower color yolk cholesterol content (p<0.05) than the control group. These results suggest that the rotational grazing Beijing-you chickens on chicory pasture in a chestnut forest were beneficial not only to improve egg quality, but also to increase the free active time and space, and to enhance the opportunity of eating plant leaves and seeds, and insects for the grazing chickens.

Previous research results (Jiang *et al.*, 2008b; Meng *et al.*, 2012; Mao *et al.*, 2015) showed that chickens reared in rotational grazing system shave higher daily gain, lower intake of supplemental feed, and better feed conversion ratio. For instance, feed conversion ratio improved from 3.83 to 3.50 in 6-8 wks, 4.15 to 3.90 in 9-12 wks, and 9.34 to 8.72 in 13-16 wks when chickens were reared in a rotational grazing system of an alfalfa pasture established in a forest at a grazing density 1800 heads/hm^2 compared with those reared on bear ground (no forage planted) in a forest (Jiang *et al.,* 2008a). Likewise, Beijing-you chickens, rotationally grazing at a density 2250 heads/hm^2 on mixed pasture (*A. hypochondriacus* and *S. bicolor* × *S. sudanense*) in a chestnut orchard and fed 15% less supplemental feed daily, presented feed conversion ratio reductions from 5.0 to 3.8 in 9-14 wks, and 9.2 to 4.3 in15-20 wks, respectively, compared with the free-range chickens (Meng *et al.*, 2012). In the present study, the rotational grazing Beijing-you chickens on chicory pasture in chestnut forest at a density of 2025 heads/hm^2 reduced ($p<0.05$) their feed conversion ratio from 4.97 to 3.48 in 8-16 wks; and 9.20 to 5.43 in 17-25 wks, representing improvements of 29.98% and 40.98%, respectively, relative to the free-range chickens. The results clearly demonstrated that the production efficiency of chickens is improved by grazing, allowing to reduce the supply of supplemental feed. In conclusion, the rotational grazing Beijing-you chickens on chicory pasture in a chestnut forest promoted better feed conversion ratio and allowed supplemental feed savings.

CONCLUSIONS

The rotational grazing system, using a chicory pasture established in a chestnut forest, promoted better live performance, carcass yield, and meat and egg quality of Beijing-you chickens compared with the free-range system herding on bare land, in addition of allowing saving 15% of supplemental feed.

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