Effect of selected fattening performance and carcass value traits on textural properties of beef

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ABSTRACT: Fifty-one crossbreed young bulls, progenies of Charolais (CH), Czech Pied (CP), Simmental (SI) and Blonde d'Aquitaine (BA) beef cattle bred at the paternal position crossed by Czech Pied at the maternal position, were reared in a typical production system and slaughtered at an average age of 578 days and live weight of 656 kg. The animals were evaluated for fattening performance and carcass quality traits (live weight at slaughter, age at slaughter, total weight gain, carcass weight, dressing percentage, net daily gain) and meat quality characteristics (dry matter, proteins, fat, ash, pH_{48}, water holding capacity, remission, collagen, area of *M. longissimus dorsi* and cooking loss). Correlation coefficients were determined in order to discover which of the above-mentioned characteristics influenced textural properties measured by Warner-Bratzler (WB) shear device and compression test (TPA). It can be concluded from the overall assessment of the correlation coefficients that slaughter age (r = 0.68, P < 0.001), net daily gain (r = –0.54, P < 0.001), average lifetime daily gain (r = –0.50, P < 0.001) and pH_{48} (r = –0.51, P < 0.001) had the major influence on the textural properties measured by WB shears. Meat texture expressed by TPA was mainly influenced by live weight at slaughter (r = 0.55, P < 0.001), carcass weight (r = 0.50, P < 0.001) and pH_{48} (r = –0.54, P < 0.001). Significant differences (P < 0.001) were found out for the age at slaughter (CH × BA) and (CP × BA), slaughter weight (CP × SI) and (CP × BA) and carcass weight (CP × BA). At the same level of significance further differences were found out for pH_{48} and water holding capacity (CP × SI), (CP × BA) and cooking loss (CH × CP). Highly significant differences (P < 0.01) in the textural properties (measured by WB shears) were determined between the following breeds: (CH × BA) and (CP × BA). At the level of significance P < 0.05, the highest differences were identified between (CH × SI) and (CP × SI). TPA test showed statistically significant differences between (CH × CP), (CP × SI) breeds at the level P < 0.05.

Keywords: bulls; fattening performance traits; meat quality; textural properties; Warner-Bratzler shears; compression test

Texture is a sensory and functional manifestation of the structural, mechanical and surface properties of foods detected through the senses of vision, hearing, touch and kinaesthetics (Szczesniak, 2002). In practise, many methods are used to evaluate meat texture. They can be grouped into three categories: sensory methods (which are fundamentally subjective), instrumental methods (known as objective) and indirect methods. Among instrumental methods, the most commonly used are compression tests, penetration tests, shear tests (frequently Warner-Bratzler shear or Kramer shear press), extension tests, and texture profile analysis tests (Kamdem and Hardy, 1994). Generally, the consumption of meat has increased. On the contrary, in the Czech Republic and other European countries the consumption of beef has dramatically decreased due to several reasons (higher price, BSE, etc.), but also because of the variability in meat quality. Especially three sensory attributes (flavour, juiciness and ten-

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derness) contribute to a consumer's perception of meat palatability or satisfaction derived from consuming beef. It has been shown that tenderness, as a textural property, is the most important factor for determining beef palatability (Jeremiah, 1982). In his paper Thompson (2002) discussed the management of meat tenderness using a carcass grading scheme which employs the concept of total quality management of those factors that impact on beef palatability. The factors were as follows: breed, growth path, hormonal growth promoters, pH/temperature window, alternative carcass suspension, marbling and ageing. From the structural point of view tenderness depends on the properties of muscle fibres and on the amount and type of connective tissue. Tenderness can be affected by rigor development, chilling, electrical stimulation, ante-mortem stress, etc. (Tornberg, 1996).

Many investigators (Mandell *et al*., 1997; Özlütürk *et al*., 2004; Sami *et al*., 2004; Sañudo *et al*., 2004 etc.) studied the relations between different production factors (breed, age, weight, etc.) and both meat quality characteristics and textural properties (especially tenderness measured mainly by WB shears and/or assessed by a sensory panel).

Breed type and slaughter weight influence carcass and meat quality characteristics in several ways, including the properties and structure of muscle and meat physiology. This, in turn, influences carcass cooling, rate of glycolysis, early pH changes and, finally, the process of transformation of muscle into meat (Sañudo *et al*., 2004).

Different breeds of cattle have a wide spectrum of fibre types in muscles (Gil *et al*., 2001) but these are not always reflected by differences in instrumental analyses using Warner-Bratzler shears or sensory panels (Koch *et al*., 1982; Jeremiah *et al*., 1997). Within the same breed type, the most important intrinsic factors affecting meat quality are age, live weight and sex (Huff and Parris, 1993). It is also relatively well documented that heavier cattle have less tender meat (Shorthose and Harris, 1990). Collagen is the major determinant of meat texture (when cold shortening is omitted) and subtle variations in the texture are dependent on the quality rather than on the quantity of collagen (Bailey and Light, 1989).

The objective of this paper was to find and explain relations (expressed by coefficients of correlation) between different fattening performance traits, carcass quality, meat quality characteristics and textural properties. The outcome of the research should help with quality assurance of beef. The second aim was to compare the level of distinction between different characteristics in four investigated crossbreds produced in the Czech Republic.

MATERIAL AND METHODS

A total of 51 young bulls were reared in a typical production system and slaughtered at an average age of 578 days and live weight of 656 kg. The group of animals consisted of Charolais (CH) n = 21, Czech Pied (CP) n = 12, Simmental (SI) n = 11 and Blonde d'Aquitaine (BA) n = 7 crossbreds that were progenies of sires of these breeds crossed by Czech Pied breed at the maternal position. The animals were evaluated for fattening performance and carcass quality traits (live weight at slaughter, age at slaughter, total weight gain, carcass weight, dressing percentage, net daily gain).

A portion of *M. longissimus pars thoracis* (MLT) (9–11th vertebrae) was removed from each carcass for the analysis of selected meat quality characteristics. Chemical analyses were based on classical methods of analysis. Kjehdahl's method was used to determine the content of total *N*, the extraction method was applied to define the content of intramuscular fat using the petroleum ether solvent. For the parameters of technological quality we defined the pH value of the muscles 48 hours *post mortem*, the colour was evaluated on the basis of reflectance per cent (wavelength 542 nm) and content of muscle pigments, for the water holding capacity we used the compression method and the content of fibrous proteins was determined by means of the content of hydroxyproline. The MLT area was determined planimetrically on the level of the 9th thoracic vertebra.

Textural properties were analysed by two different objective methods. Meat was vacuum packaged prior to cooking in a water bath until the internal temperature reached 70°C for one hour. Cooking loss was determined by weighing the samples before and directly after cooking. Percentage of total cooking loss (evaporative and drip loss) was calculated as follows:

$$\text{Cooking loss} = [(\text{raw weight} - \text{cooked weight})/\text{raw weight}] \times 100$$

Maximum load and toughness (amount of force necessary to break the sample) were assessed using the Warner-Bratzler device shearing until the total break of the sample. The test was conducted according to methodology described by Christensen *et al.* (2000). The bicyclical compression test was used to simulate molars during a mastication process. Samples were compressed up to 80% deformation (K = 0.8) and maximum stress (N/cm^2) was determined. The methodology of compression test was according to Houška *et al.* (1994). Both probes were attached to TIRA-test machine.

Mathematical and statistical tests of average data on the whole and for each breed separately were carried out using the statistical UNISTAT 5.0 package. Summary statistics (mean, standard deviation, coefficient of variation), coefficients of correlation and three selective t-tests with 95, 99 and 99.9% level of significance were used.

RESULTS

Selected fattening performance and carcass quality traits of fifty-one young bulls are presented in Table 1. The highest slaughter age was in Blonde d'Aquitaine breed (BA = 683.3 days), followed by Simmental (SI = 645.4 days), Charolais (CH = 548.1) and Czech Pied (CP = 505.1). The same order was in slaughter weight and carcass weight. CH breed had the highest average lifetime daily gain (1.147 kg) as well as net daily gain (0.701 kg). The highest dressing percentage was determined in BA breed (59.02%). Table 2 shows statistically significant differences in fattening performance and carcass quality traits. It is clear from Table 2 that BA versus CH and CP differed significantly in slaughter age at the level of significance $P < 0.001$ and SI versus

Table 1. Selected fattening performance and carcass quality traits (n = 51)

Item/Breed	Charolais			Czech Pied			Simmental			Blonde d'Aquitaine		
	$\bar{x}$	$s_{\bar{x}}$	V(%)	$\bar{x}$	$s_{\bar{x}}$	V(%)	$\bar{x}$	$s_{\bar{x}}$	V(%)	$\bar{x}$	$s_{\bar{x}}$	V(%)
Slaughter age (days)	548.1	78.06	14.24	505.1	50.35	9.97	645.4	113.30	17.56	683.3	20.75	3.04
Slaughter weight (kg)	653.3	76.06	11.64	587.3	50.76	8.64	694.1	86.69	12.49	722.3	72.48	10.03
Average lifetime daily gain (kg)	1.147	0.132	11.47	1.106	0.062	5.63	1.038	0.080	7.68	1.015	0.116	11.39
Carcass weight (kg)	378.7	43.36	11.45	339.8	33.40	9.83	389.0	58.64	15.08	424.7	33.58	7.91
Dressing percentage (%)	57.99	0.96	1.65	57.81	1.62	2.80	55.90	2.39	4.28	59.02	3.07	5.20
Net daily gain (kg)	0.701	0.074	10.53	0.674	0.046	6.79	0.608	0.058	9.61	0.622	0.536	8.61

Charolais n = 21; Czech Pied n = 12; Simmental n = 11; Blonde d'Aquitaine n = 7

Table 2. Statistically significant differences in fattening performance and carcass quality traits

Item/Breed	CH × CP	CH × SI	CH × BA	CP × SI	CP × BA	SI × BA
Slaughter age (days)	n.s.	**	***	**	***	n.s.
Slaughter weight (kg)	*	n.s.	n.s.	***	***	n.s.
Average lifetime daily gain (kg)	n.s.	*	*	*	*	n.s.
Carcass weight (kg)	*	n.s.	*	*	***	n.s.
Dressing percentage (%)	n.s.	**	n.s.	*	n.s.	*
Net daily gain (kg)	n.s.	**	*	**	*	n.s.

CH = Charolais; CP = Czech Pied; SI = Simmental; BA = Blonde d'Aquitaine
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; n.s. = not significant

CP and CH at $P < 0.01$. No significant differences were found out in slaughter weight between CH × SI, CH × BA and SI × BA; on the contrary, highly significant ($P < 0.001$) differences were identified between CP versus SI and CP × BA. Net daily gain significantly differed ($P < 0.01$) between CH × SI and CP × SI and at the level $P < 0.05$ between CH × BA and CP × BA as well.

The evaluation of meat quality was based on 12 characteristics (Table 3). The assessment of statistically significant differences is presented in Table 4. No significant differences between breeds were found out in chemical composition (dry matter, total protein, fat and ash) except for total collagen content that ranged from 1.41 g/100g of muscle (CP) to 2.18 g/100g (SI and BA) and differed significantly ($P < 0.01$) between CH × SI, CH × BA and CP × BA. Out of the physical properties the largest differences were found in pH_{48} accompanied by water holding capacity, which corresponded to each other. It decreased in the order CP, CH, BA and SI. The value of cooking loss ranged from 28.74% (BA) to 30.31% (CH), on the contrary for CP it was only 22.94%, i.e. significantly lower. The lowest reflectance 4.10% was measured for CP, on the other hand the highest was determined for CH (6.29%). Textural properties were expressed by WB and TPA analysis. The lowest shear force was recorded for CP (84.58 N) followed by CH (86.63 N), SI (110.98 N) and BA (119.95 N). No significant differences were found out between CH × CP and SI × BA. TPA analysis proved statistically significant differences ($P < 0.05$) between CH × CP and CP × SI. The coefficient of variation was the highest for total collagen content, fat content and texture measurements, on the contrary it was lowest was for total protein, ash and dry matter.

Table 5 shows coefficients of correlation between selected characteristics. The highest correlations ($P < 0.001$) were reached between slaughter weight and carcass weight ($r = 0.97$), pH_{48} and water holding capacity ($r = 0.93$), WB shear force and slaughter age ($r = 0.68$), cooking loss and water holding capacity ($r = -0.66$). Significant ($P < 0.001$) coef-

Table 3. Selected meat quality characteristics ($n = 51$)

Item/Breed	Charolais			Czech Pied			Simmental			Blonde d'Aquitaine		
	$\bar{x}$	$s_{\bar{x}}$	V(%)	$\bar{x}$	$s_{\bar{x}}$	V(%)	$\bar{x}$	$s_{\bar{x}}$	V(%)	$\bar{x}$	$s_{\bar{x}}$	V(%)
Dry matter (%)	24.50	0.76	3.09	24.57	0.98	3.99	24.57	0.75	3.06	24.31	0.77	3.16
Total protein (%)	21.43	0.32	1.49	21.35	0.47	2.22	21.45	0.56	2.63	21.77	0.23	1.04
Fat (%)	1.84	0.65	34.97	2.03	0.65	31.90	1.91	0.90	47.22	1.38	0.56	40.81
Ash (%)	1.10	0.04	3.56	1.09	0.03	3.09	1.09	0.02	2.05	1.11	0.03	2.46
pH_{48}	5.69	0.30	5.32	6.08	0.32	5.20	5.44	0.06	1.13	5.46	0.06	1.07
Water holding capacity (%)	78.30	4.44	5.67	86.20	5.89	6.84	75.05	2.30	3.06	76.04	2.00	2.63
Reflectance (%)	6.29	1.89	30.12	4.10	1.55	37.82	5.55	1.42	25.67	5.10	1.92	37.70
Total collagen (g/100g of muscle)	1.42	0.62	43.84	1.41	0.33	23.66	2.18	0.80	36.72	2.18	0.44	20.17
MLT area (cm^2)	91.89	19.48	21.20	75.42	8.37	11.10	98.75	12.06	12.21	140.80	36.20	25.71
Cooking loss (%)	30.31	2.93	9.67	22.94	4.45	19.42	29.39	3.23	10.98	28.74	1.99	6.94
WB shear force (N)	86.63	23.53	27.16	84.58	20.07	23.73	110.98	23.74	21.39	119.95	26.98	22.49
TPA1 (1st compression) (N/cm^2)	239.39	91.06	38.04	161.62	81.85	50.64	254.23	94.81	37.29	236.96	68.06	28.72
TPA2 (2nd compression) (N/cm^2)	210.84	76.99	36.51	142.56	69.70	48.89	216.46	78.66	36.34	202.22	56.64	28.01

Charolais $n = 21$; Czech Pied $n = 12$; Simmental $n = 11$; Blonde d'Aquitaine $n = 7$

Table 4. Statistically significant differences in meat quality characteristics

Item/Breed	CH × CP	CH × SI	CH × BA	CP × SI	CP × BA	SI × BA
Dry matter (%)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Total protein (%)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Fat (%)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Ash (%)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
pH_{48}	**	*	n.s.	***	***	n.s.
Water holding capacity (%)	***	*	n.s.	***	***	n.s.
Reflectance (%)	**	n.s.	n.s.	*	n.s.	n.s.
Total collagen (g/100g of muscle)	n.s.	**	**	*	**	n.s.
MLT area (cm^2)	*	n.s.	***	***	***	*
Cooking loss (%)	***	n.s.	n.s.	**	**	n.s.
WB shear force (N)	n.s.	*	**	*	**	n.s.
TPA1 (1st compression) (N/cm^2)	*	n.s.	n.s.	*	n.s.	n.s.
TPA2 (2nd compression) (N/cm^2)	*	n.s.	n.s.	*	n.s.	n.s.

CH = Charolais; CP = Czech Pied; SI = Simmental; BA = Blonde d'Aquitaine
*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

Table 5. Coefficients of correlation between selected characteristics (overall assessment)

Item/Item	Average lifetime daily gain (kg)	Slaughter age (days)	Slaughter weight (kg)	Carcass weight (kg)	Net daily gain (kg)	Water holding capacity (%)	pH_{48}	Total collagen (g/100 g of muscle)
Slaughter weight (kg)	0.08	0.76***	1.00	0.97***	0.00	–0.49***	–0.59***	0.40**
pH_{48}	0.12	–0.57***	–0.59***	–0.52***	0.22	0.93***	1.00	–0.49***
Total collagen (g/100g of muscle)	–0.25*	0.45***	0.40**	0.33**	–0.29*	–0.42**	–0.49***	1.00
Proteins/HP (mg/100g)	0.15	–0.25	–0.19	–0.16	0.23	0.55***	0.52***	–0.29*
Cooking loss (%)	0.08	0.21	0.31*	0.30*	0.04	–0.66***	–0.56***	0.07
WB shear force (N)	–0.50***	0.68***	0.43***	0.36**	–0.54***	–0.43***	–0.51***	0.44***
TPA1 (N/cm^2)	–0.08	0.47***	0.55***	0.50***	–0.16	–0.47***	–0.54***	0.44***
TPA2 (N/cm^2)	–0.06	0.44***	0.53***	0.48***	–0.13	–0.47***	–0.53***	0.41**

HP = hydroxyproline; *$P < 0.05$; **$P < 0.01$; ***$P < 0.001$

ficients of correlation were also found between cooking loss and pH_{48} (r = –0.56), proteins/hydroxyproline and water holding capacity (r = 0.55), TPA 1st and slaughter weight (0.55), TPA 1st and pH_{48} (r = –0.54).

DISCUSSION

The aim of this paper was to evaluate the effect of selected quality characteristics on textural properties of beef, including breed, age and weight. As the breeds were slaughtered at the different slaughter age and weight, the evaluation of breed effect is debatable.

Slaughter age

A highly significant correlation ($P < 0.001$, $r = 0.76$) was found between slaughter age and slaughter weight. Slaughter age had a significant effect ($P < 0.001$) and was positively correlated ($r = 0.68$) with WB shear force measurements. Although a higher correlation coefficient was found out in the present study, this result is in accordance with the findings of Mandell *et al.* (1997), who also reported positive correlations ($r = 0.29$, $P = 0.03$) between age at slaughter and shear force.

Cross *et al.* (1984) reported that the total collagen level was significantly affected by sex and age. The effect of age was confirmed in the present study as well, when age was positively correlated ($P < 0.001$, $r = 0.45$) with total collagen content.

Total collagen content

However, Bailey and Light (1989) reported an opposite fact that the collagen concentration did not change significantly during growth until slaughter, but collagen solubility decreased with animal weight and age. Soluble collagen is significantly related to the contribution of connective tissue to toughness, and tenderness differs among muscles from various anatomical regions (Cross *et al.*, 1973). In the present study both indicators (animal weight, animal age) were positively correlated (Table 5) with objective measurement of toughness (WB shear force and compression test).

Our results of total collagen concentration in muscles in the case of CH and CP were similar to those reported by Sañudo *et al.* (2004); on the other hand, the values for SI and BA were slightly higher. The results showed significant differences ($P < 0.01$) in the total collagen content between CH × SI, CH × BA, CP × BA combinations, which corresponds to Sañudo's *et al.* (2004) findings that the total collagen content is affected by breed type.

In 1977 Dransfield showed a clear correlation between total collagen content and muscle toughness. A high positive correlation between WB shear force and total collagen content ($P < 0.01$, $r = 0.723$) was also demonstrated by Torrescano *et al.* (2003). This fact was proved in our experiment too. WB and compression test were positively correlated with total collagen content ($P < 0.001$, $r = 0.44$ for both WB and TPA), and therefore, the results reported by Dransfield (1977) and Torrescano *et al.* (2003) are consistent with the findings of the present study.

pH_{48}

The course of glycolysis as a part of early post mortem changes is evaluated by the pH value. The average pH_{48} values did not exceed the critical value (6.2) defining the incidence of DFD syndrome for any breed. However, the highest average pH value was recorded for CP (6.08), which could indicate the inclination to DFD syndrome, probably caused by increased perceptiveness of CP to ante-mortem stress. The latter statement can be supported by the fact that besides pH CP meat demonstrated the highest value of water holding capacity, the lowest cooking loss and reflectance (Table 3).

The pH value can be important for meat tenderness. Yu and Lee (1986) established that high pH meat (above 6.3) was most tender, followed by low (below 5.8) and intermediate (5.8–6.3) pH meats. Therefore our results are in agreement with Yu's conclusion. The lowest WB and TPA values were recorded for CP (in the case of WB shear force the value was insignificantly lower compared to CH, but significantly lower than in SI ($P < 0.05$) and BA ($P < 0.01$)), so the meat from CP bulls was evaluated as the most tender.

Cooking loss

The cooking loss values for CH, SI, BA were similar to the results of Scheeder *et al.* (2001), on the contrary, the value for CP was considerably lower.

Gullet *et al.* (1996) found total cooking loss to be negatively correlated with tenderness. No relation between cooking loss and WB was proved. On the other hand, the positive relation ($r = 0.41$; $P < 0.01$) was found out between cooking loss and toughness expressed by compression test. The latter mentioned fact is in accordance with the findings of Sochor *et al.* (2005), who reported a positive correlation ($r = 0.83$) between compression test and cooking loss of beef.

WB shear force

In comparison with Özlütürk *et al.* (2004) we demonstrated higher WB values (86.63 N; versus Özlütürk's 71.4 N) for CH and lower for SI (110.98 N; versus Özlütürk's 137.7 N).

The values of WB measurements were significantly lower in CH and CP compared to SI and BA (Tables 3 and 4) and correlated with slaughter weight (positive correlation $r = 0.43$) and slaughter age ($r = 0.68$). The same relation between age and tenderness was reported by Shorthose and Harris (1990). Thus the meat from lighter and younger animals was significantly more tender, however with larger variation within WB values. From the texture point of view the differences in tenderness can be explained by the content of total collagen that was higher in the case of SI and BA (it means in the older animals). These statements can be supported by the correlation coefficient between WB and collagen content ($r = 0.44$).

Furthermore, Bailey and Light (1989) reported that the collagen solubility decreased with animal weight and age. Therefore the heated meat from older animals is tougher even if the total collagen content is the same.

TPA (compression test)

As it is clear from the previous description, there were significant differences (even at the level of $P < 0.001$) between the breeds in slaughter weight and age.

Out of the fattening performance traits, the results of TPA were mostly influenced by the weight-age effect. Significant differences ($P < 0.05$) were found out between mean TPA values of CH × CP and CP × SI. Furthermore, the results of TPA were influenced by slaughter weight ($r = 0.55$) to a larger extent than by slaughter age ($r = 0.47$). According to Sañudo *et al.* (2004), the differences are related to the stronger texture of connective tissue in heavier animals. The stronger texture is a result of some hypothetical differences in the angle between the collagen fibres and the myofibrillar compounds and/or of the superior thickness of their perimysium and endomysium (Torrescano *et al.*, 2003).

In reference to total collagen content and TPA, it could be indicated that the connective tissue had a different quality because this tissue depends on the collagen content and the number of links between collagen molecules (Shorthose and Harris, 1990). In our case, the same positive correlation ($r = 0.44$) between collagen content and TPA was observed as it was determined for WB test. It implicates that total collagen content influences both textural properties (measured by WB and TPA) at the same level.

CONCLUSIONS

In conclusion, pH_{48} value had a significant influence on WB shear force and compression test. It means that better tenderness can be expected in beef with higher pH_{48} value. The higher cooking loss had a negative effect on tenderness measured by TPA.

The evaluation of meat tenderness by WB showed that out of the fattening performance traits, slaughter age and slaughter weight had the strongest effect (positive correlation with meat toughness). To compare these two characteristics it is necessary to state that the toughness measured by WB is more influenced by slaughter age ($r = 0.68$) than slaughter weight ($r = 0.43$). This fact can be explained by the content of total collagen that was higher in older animals and by the change of the soluble to insoluble collagen ratio with age. On the other hand, the results of compression test (TPA) were more influenced by slaughter weight ($r = 0.55$), which can be explained by the stronger connective tissue in heavier animals. No relationship between WB test and TPA test was found. It indicates that these tests measure different aspects of meat texture. Therefore further research including sensory analysis would be helpful before definite conclusions can be drawn on the effect of selected quality characteristics on textural properties of beef.

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