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TEXTURE ANALYSES OF TWO SCHIZOTHORACINAE FISHES IN TIBET AUTONOMOUS REGION, CHINA

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Abstract: *Schizothorax macropogon* and *Ptychobarbus dipogon* are important economic fishes in the Yarlung Zangbo River. Both are Schizothoracinaes containing a variety of essential fatty acids with high nutritional values. As food products, the textural characteristics of their meat determine important factors like taste or methods of treatment. To explore the preservation and utilization of fish resources in the Tibet Autonomous Region, China, the texture profile analysis (TPA) method was used to analyze 12 textural parameters. Fish were captured from the Yarlung Zangbo River in Shigatse and Nyingchi City. Principal component analysis showed that the texture of *P. dipogon* captured from the Nyingchi segment was different from the same species captured in the Shigatse segment, and different from *S. macropogon* captured from both segments. Factorial analysis indicated that the textural characteristics of Schizothoracinae fishes in Tibet Autonomous Region can be summarized as hardness indices, overcome attraction indices and contractility indices, of which the accumulated variance contribution rate of the first four principal component factors was 81.472%. The three categories of the four principal component axes could be the main deciding parameters of the textural characteristics of Schizothoracinae fishes in Tibet Autonomous Region. This provides scientific data for subsequent development and utilization of Schizothoracinae fishes from the Yarlung Zangbo River in different geographical areas.

Key words: Tibet Autonomous Region; The Yarlung Zangbo River; *Schizothorax macropogon*; *Ptychobarbus dipogon*; Textural characteristics

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Schizothorax macropogon and *Ptychobarbus dipogon* (Family Schizothoracinae) are important economic fish in the Yarlung Zangbo River. Their fatty acid composition is similar to deep-sea fish. Essential fatty acid contents are as high as 30%[1], which can regulate blood lipids and reduce cardiovascular disease among other benefits. The flesh of both fish is widely considered delicious with high nutritional value. However, slow growth, low fecundity, increased catch, exotic fish invasion and other factors have led to population decline[2]. Thus, *Schizothorax macropogon* and *Ptychobarbus dipogon* were listed as endangered fish on the Chinese Species Red List in 2008. Therefore, protection and reasonable processing and utilization of *Schizothorax macropogon* and *Ptychobarbus dipogon* are critical.

Textural characteristics represent a foodstuff's structure and response to external forces. Examples of textural characteristics include hardness, cohesiveness, adhesion, chewiness and others, which are im-

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portant indices for exploitation and utilization of food[3, 4]. The study of textural characteristics can improve utilization rates of raw food materials, reduce waste, and increase the economic value of raw food materials. Textural characteristics can affect the treatment process of a product: for example, when developing low-fat products to replace fat, one needs to build suitable viscosity to retain reasonable taste. At present, studies on *Schizothorax macropogon* and *Ptychobarbus dipogon* mainly focus on taxonomy[5], origin and evolution[6, 7], chromosome characteristics[8, 9], fatty acid composition[10], and growth and reproduction characteristics[11, 12]. Studies on textural characteristics of *Schizothorax macropogon* and *Ptychobarbus dipogon* have not been reported.

In order to protect *Schizothorax macropogon* and *Ptychobarbus dipogon* and improve their utilization, we carried out texture studies and analyzed the characteristics of raw materials. Specifically, we addressed the textural characteristics of *Schizothorax macropogon* and *Ptychobarbus dipogon* from the Yarlung Zangbo River in different geographical areas. This research is of great significance for proper development and utilization of Schizothoracinae fishes from the Yarlung Zangbo River and ultimately processing products of Schizothoracinae fishes in Tibet Autonomous Region.

1 Materials and Methods

1.1 Materials

In April 2013, *Schizothorax macropogon* and *Ptychobarbus dipogon* were collected by trawl fishing practices from the Yarlung Zangbo River in Shigatse and Nyingchi City. At each site, we collected 5 individuals of each species, thus a total of 20 live individuals were collected. Individual fish size was controlled around 30 cm, gender has not been considered tentatively.

1.2 Methods

Sample preparation Following collection, fish samples were dissected after holding in laboratory aquaria for one hour. First, each individual was hit on its head by a blunt instrument, and then cleaned with tap water after entrails, gills, and scales were removed. Dorsal muscles (15 cm length by 2 cm width) were taken from both sides of the back, starting from the back of the pectoral fin towards the tail. Red muscles were removed, and cut into sample fillets of 1 cm × 1 cm × 0.6 cm (length × width × height). There were four fish fillets in each side. The samples were sealed and preserved at –20℃.

Determination method Textural parameter setting: Texture analyzer (TMS-Pro), testing speed before experiment: 20 mm/min; experimental test speed: 40 mm/min; starting force: 0.1 N; test maximum distance: 7 mm; return speed: 60 mm/min; input deformation: 30%; cycle index: Auto, twice; interval time: Auto, 0s.

To determine processing order, we placed the samples on the side of the texture analyzer with muscles placed back, lined up, and checked one by one in sequence. Afterwards, the test was run and the date was recorded. As experimental design we used the TPA with a single factor for design, a 75 mm cylindrical probe was utilized with four parallel samples. Furthermore, a single factor design was used to test shearing force by using a cutting probe to simulate human teeth. Sample treatment was the same as the TPA test. All data analysis was performed using R (version 2.14.1). Single factor analysis of variance (ANONA) and Least Significant Difference (LSD) tests were used to analyze the differences of two Schizothoracinae fishes. Furthermore, principal component analysis (PCA) was used to analyze the textural characteristics these fishes.

2 Results

2.1 Data analysis

Experimental results of texture profile analysis (TPA) Mean hardness of *Schizothorax macropogon* from the Yarlung Zangbo River in Shigatse was 2.31 and *Ptychobarbus dipogon* from the Yarlung Zangbo River in Nyingchi City was 1.11. Texture analysis showed that there were significant differences in average hardness between *Schizothorax macropogon* and *Ptychobarbus dipogon* in the same river ($P<0.05$). The hardness of *Schizothorax macropogon* was significantly greater than that of *Ptychobarbus dipogon*, which indicates that the meat of *Schizothorax macropogon* was harder and chewier. There were significant differences in average hardness for *Schizothorax macropogon* between Shigatse and Nyingchi ($P<0.05$). Hardness of *Schizothorax macropogon* from Shigatse was significantly greater than that of *Schizothorax macropogon* from Nyingchi, which showed that different geographical environments could affect the hardness characteristics of Schizothorax fishes.

Mean elasticity of *Ptychobarbus dipogon*was 0.98 for Shigatse, and 0.71 for Nyingchi. Significant differences in mean elasticity value were found between *Ptychobarbus dipogon* in Shigatse and Nyingchi ($P<0.05$), as well as *Schizothorax macropogon* ($P<0.05$). Comparing within species, the average elasticity value of fish from Shigatse was significantly greater than fish from Nyingchi, which shows that

different geographical water environment can affect the elasticity characteristics of Schizothorax fishes.

Mean adhesion of *Ptychobarbus dipogon* from Shigatse and Nyingchi equaled 0.03 and *Schizothorax macropogon* from Shigatse and Nyingchi equaled 0.02, thus *Ptychobarbus dipogon* was more adhesive than *Schizothorax macropogon*. This result showed that species rather than location were the main factors in adhesion.

Mean consistency of *Ptychobarbus dipogon* from Shigatse was 0.58 while *Ptychobarbus dipogon* from Nyingchi was 0.46. There were significant differences in consistency of *Ptychobarbus dipogon* between Shigatse and Nyingchi (P<0.05). There were significant differences in consistency between *Ptychobarbus dipogon* from Nyingchi and *Schizothorax macropogon* from Shigatse and Nyingchi (P<0.05). This showed that cohesiveness of schizothorax fish was related to both species and environment.

Schizothorax macropogon from Shigatse had the highest gumminess at 1.21, while *Ptychobarbus dipogon* from Nyingchi had the lowest gumminess at 0.50. There were significant differences in gumminess of *Schizothorax macropogon* between Shigatse and Nyingchi (P<0.05). Gumminess of *Schizothorax macropogon* from Shigatse was significantly greater than that of *Schizothorax macropogon* from Nyingchi. There were significant differences in gumminess between *Ptychobarbus dipogon* and *Schizothorax macropogon* (P<0.05). Gumminess of *Schizothorax macropogon* was significantly greater than that of *Ptychobarbus dipogon*. In conclusion, the difference in gumminess of Schizothorax fish was related to both species and environment.

Mean chewiness of *Schizothorax macropogon* from Shigatse and *Ptychobarbus dipogon* from Nyingchi was the smallest at 1.13 and 0.36, respectively. Chewiness of *Schizothorax macropogon* was significantly greater than *Ptychobarbus dipogon* inboth Shigatse and Nyingchi. This signified that *Schizothorax macropogon* meat was chewier. There were significant differences within species between Shigatse and Nyingchi (P<0.05). There were also significant differences between species from the same river (P<0.05). In conclusion, the chewiness of both species was related to both environment and species.

Experimental results of shearing force teating Tests of maximum power peak showed that there were significant differences for *Ptychobarbus dipogon* between Shigatse and Nyingchi (P<0.05). This showed that different habitats could affect the maximum strength peak of *Ptychobarbus dipogon*. There were significant differences in the maximum power peak between *Ptychobarbus dipogon* from Nyingchi and *Schizothorax macropogon* from Shigatse and Nyingchi (P<0.05). The maximum power peak of *Schizothorax macropogon* was greater than that of *Ptychobarbus dipogon*.

Mean displacements at maximum hardness of *Ptychobarbus dipogon* from Nyingchi and Shigatse was 6.09 and 5.10 respectively. Furthermore, these values represent the maximum and minimum, respectively. There were significant differences in displacement at maximum hardness of *Ptychobarbus dipogon* between Shigatse and Nyingchi (P<0.05). This showed that the habitat of *Ptychobarbus dipogon* can affect their displacements at maximum hardness.

The test result of doing work at maximum hardness showed that doing work at maximum hardness of *Schizothorax macropogon* is greater than that of *Ptychobarbus dipogon*. There were significant differences in doing work at maximum hardness in all four samples (P<0.05). In conclusion, environment and

Tab. 1 The textural characteristics analysis of two Schizothoracinae fishes in the Tibet Autonomous Region

Single factor index	PD_S1 μ±Std.D	PD_S2 μ±Std.D	SM_S1 μ±Std.D	SM_S2 μ±Std.D
HD1	1.26±0.68^{bc}	1.11±0.41^{c}	2.31±1.02^{a}	1.70±1.02^{b}
HD2	1.12±0.59^{bc}	0.88±0.37^{c}	2.05±0.84^{a}	1.49±0.89^{b}
SN	0.98±0.18^{a}	0.71±0.17^{c}	0.93±0.10^{a}	0.82±0.18^{b}
AN	0.03±0.01^{b}	0.03±0.01^{a}	0.02±0.01^{b}	0.02±0.01^{a}
CN	0.58±0.06^{a}	0.46±0.10^{c}	0.54±0.06^{a}	0.53±0.07^{ab}
GN	0.73±0.38^{bc}	0.50±0.20^{c}	1.21±0.43^{a}	0.89±0.52^{b}
CHN	0.72±0.45^{b}	0.36±0.21^{c}	1.13±0.44^{a}	0.77±0.51^{b}
MH	5.13±3.15^{a}	2.60±2.43^{b}	5.85±3.02^{a}	6.16±2.70^{a}
DH	5.10±0.71^{b}	6.09±2.70^{a}	5.50±0.78^{ab}	5.53±1.72^{a}
WH	9.23±5.57^{a}	4.27±3.20^{b}	12.10±5.56^{a}	10.83±4.58^{a}
IF	1.20±2.33^{ab}	0.73±1.48^{b}	2.24±2.70^{a}	1.85±3.04^{ab}
DF	8.39±3.62^{a}	6.55±4.43^{b}	8.08±3.17^{ab}	8.02±3.75^{b}

Notes: (1) Different letters in the same line indicated significant differences between treatments (P<0.05). (2) PD_S1 stands for the *Ptychobarbus dipogon* from the Yarlung Zangbo River in Shigatse; PD_S2 stands for the *Ptychobarbus dipogon* from the Yarlung Zangbo River in Nyingchi; SM_S1 stands for the *Schizothorax macropogon* from the Yarlung Zangbo River in Shigatse; SM_S2 stands for the *Schizothorax macropogon* from the Yarlung Zangbo River in Nyingchi. (3) HD1 stands for the first hardness value, unit: Newtons; HD2 stands for the second hardness value, unit: Newtons; SN stands for elasticity, unit: m; AN stands for adhesion, unit: J; CN stands for cohesion, non dimensional; GN stands for gumminess, unit: Newtons; CHN stands for chewiness or palatability, unit: J; MH stands for maximum power peak value, unit: Newtons; DH stands for displacements at the maximum hardness, unit: mm; WH stands for the work done at maximum hardness, unit: mJ; IF stands for initial destructive force, unit: Newtons; DF stands for the displacement at initial destructive force, unit: mm. (4) The relative abbreviations of Fig 1, Tab. 2 and Tab. 3 are the same as the abbreviations of Tab. 1

species can affect doing work at maximum hardness of these two kinds of Schizothorax fish.

The largest mean initial destructive force was *Schizothorax macropogon* from Shigatse at 2.24. The smallest mean initial destructive force was *Ptychobarbus dipogon* from Nyingchi at 0.73. Mean initial destructive force of *Schizothorax macropogon* was greater than that of *Ptychobarbus dipogon*. This showed that species was the main factor in differences of initial destructive force of Schizothorax fish.

Mean displacement at initial destructive force of *Ptychobarbus dipogon* from Shigatse and Nyingchi were 8.39 and 6.55, furthermore, this represented the maximum and minimum values, respectively. Significant differences were found for both *Ptychobarbus dipogon* and *Schizothorax macropogon* between Shigatse and Nyingchi.

2.2 Textural characteristics analysis between *Schizothorax macropogon* and *Ptychobarbus dipogon*

Using the PCA method, we found significant differences in texture between two species of Schizothorax fish from the Yarlung Zangbo River in both Shigatse and Nyingchi (Fig. 1). Comparing textural characteristics indices of both species from Shigatse with both species from Nyingchi, the fish from Shigatse had good elasticity, tight muscle tissue structure, strong cohesion, and their meat was more chewy. The elasticity, adhesion, and cohesion characteristics of *Ptychobarbus dipogon* from Shigatse were superior to

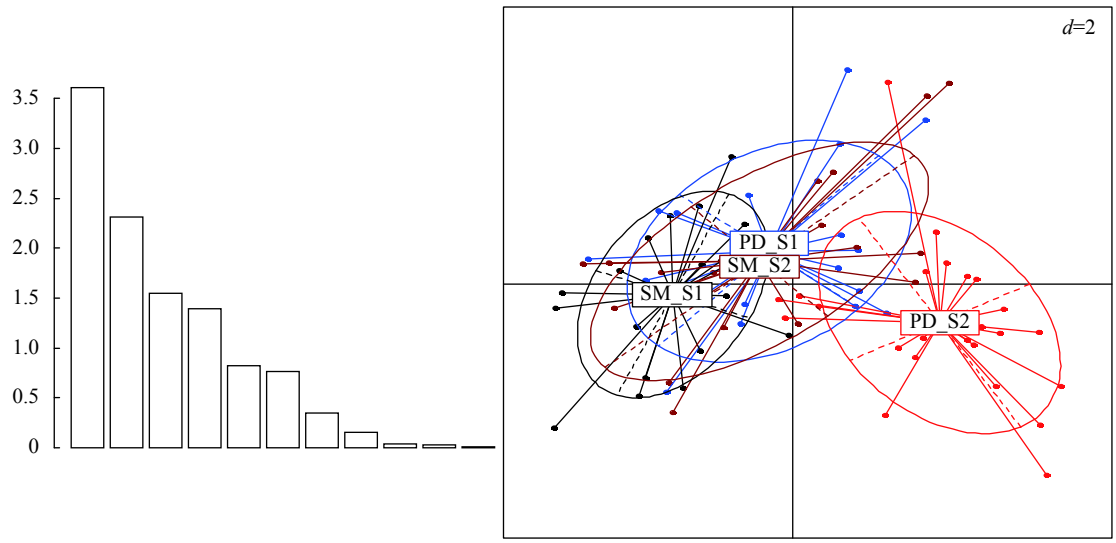

Fig. 1　The textural characteristics of two schizothoracinae fishes in the Tibet Autonomous Region based on PCA analysis

PD_S1 stands for the *Ptychobarbus dipogon* from the Yarlung Zangbo River in Shigatse; PD_S2 stands for the *Ptychobarbus dipogon* from the Yarlung Zangbo River in Nyingchi; SM_S1 stands for the *Schizothorax macropogon* from the Yarlung Zangbo River in Shigatse; SM_S2 stands for the *Schizothorax macropogon* from the Yarlung Zangbo River in Nyingchi City

Tab. 2　Total variance decomposition tables of textural characteristics of two schizothoracinae fishes in Tibet Autonomous Region

Components	Initial eigenvalues			Extraction sums of squared loadings			Rotation sums of squared loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
HD1	4.156	34.630	34.630	4.156	34.630	34.630	3.968	33.066	33.066
HD2	2.566	21.383	56.013	2.566	21.383	56.013	2.334	19.446	52.513
SN	1.680	13.999	70.012	1.680	13.999	70.012	1.881	15.672	68.185
AN	1.375	11.461	81.472	1.375	11.461	81.472	1.594	13.287	81.472
CN	0.890	7.417	88.889						
GN	0.813	6.775	95.663						
CHN	0.283	2.362	98.025						
MH	0.148	1.230	99.256						
DH	0.045	0.376	99.631						
WH	0.030	0.249	99.880						
IF	0.012	0.098	99.979						
DF	0.003	0.021	100.000						

Tab. 3 Rotated principal component matrix of textural characteristics for two Schizothoracinae fishes in Tibet Autonomous Region

Index	Principal Component			
	1	2	3	4
HD1	0.984	–0.021	–0.114	–0.010
HD2	0.986	0.015	–0.051	0.000
SN	0.331	0.223	0.837	0.109
AN	0.034	–0.440	–0.132	0.299
CN	–0.037	0.235	0.899	–0.087
GN	0.987	0.034	0.109	–0.025
CHN	0.943	0.080	0.287	0.015
MH	–0.040	0.893	0.166	–0.091
DH	–0.045	–0.176	0.213	0.706
WH	0.106	0.911	0.216	0.038
IF	0.191	0.605	–0.325	0.445
DF	0.007	–0.055	0.140	–0.882

Schizothorax macropogon from Shigatse, yet hardness, gumminess, and chewiness of *Schizothorax macropogon* were superior to *Ptychobarbus dipogon*. This showed that *Ptychobarbus dipogon* was tender, highly elasticity, and soft, but *Schizothorax macropogon* was more chewy. Except for adhesion, the other characteristic indices of *Schizothorax macropogon* from Nyingchi were superior to that of *Ptychobarbus dipogon* from Nyingchi, which showed that *Schizothorax macropogon* has tight muscle tissue structure, good elasticity, high enderness, and the muscle is chewier.

Using factorial analysis to analyze the textural characteristics of two kinds of Schizothorax fish from the Yarlung Zangbo River in Tibet autonomous region (Tab. 1), the cumulative variance contribution rate of the lead four principal components was 81.472% (Tab. 2 & 3). Twelve textural characteristics parameters were concluded to three categories. The first category was the relative indices of hardness from the texture analysis, which included the first hardness value, the second hardness value, the gumminess, and the chewiness measurements (principal component 1; PC1). The second category was the correlation indices of incision and contact attraction, including adhesion, maximum power peak value, doing work at maximum hardness, initial destructive force, the average displacement at the maximum hardness, and the displacement at the initial destructive force (principal component 2, principal component 4; PC2, PC4). The third category was related to the contractility of the fish, including cohesion and elasticity (principal component 3; PC3). The three categories of four principal component indices can be regarded as main decision parameters of the textural characteristics of Schizothoracinae fishes from the Yarlung Zangbo River.

3 Discussion

Texture is an important index of food, which when combined with appearance, flavor, and nutrition together constitute the four major elements of food quality[13]. This research shows that hardness, elasticity, and adhesion are the main texture indices of *Ptychobarbus dipogon* and *Schizothorax macropogon* from the Yarlung Zangbo River. Hardness tests showed that within the same species, fish from Shigatse has greater hardness and tighter muscle tissue structure compared to fish from Nyingchi. One potential cause may be higher elevation and lower water temperatures in Shigatse among other hydrological conditions. As a result, fish from Yarlung Zangbo River in Shigatse may produce adaptive mechanisms, such as tighter muscle tissue structure and greater hardness. Elastic tests showed that within the same species, there were significant differences between fish from Shigatse and fish from Nyingchi, which may be related to the higher elevation, lower water temperatures, and fast flow of the Yarlung Zangbo River in Shigatse. Adhesion tests showed that *Ptychobarbus dipogon* had 50% greater adhesione compared to *Schizothorax macropogon*. Comprehensive analyses of hardness, elasticity, and adhesion showed species of Schizothorax fish was the main factor in textural characteristic differences. However, elevation, water temperature, and other hydrological conditions are also important factors of textural characteristic differences between species of Schizothorax fish.

Aquatic products are perishable, thus many studies have focused on the best storage conditions through texture studies. The research of Yang Pei-Zhou, *et al*. [14]showed that the hardness, elasticity, adhesiveness, cohesiveness, and chewiness of Smelly Mandarin fish significantly improved and reached optimum condition through eight days fermentation. Ayala, *et al*. [15] studied the effects of refrigeration and refrigeration after vacuum-packaging on the texture of gilthead sea bream fillets. The results showed that as storage time was prolonged, textural parameters of chilled fish significantly decreased whether vacuum or non-vacuum sealed. Wang Qiao-Yi, *et al*. [16] tested hardness, adhesiveness, elasticity, chewiness, gumminess, cohesiveness, and resilience of tilapia muscle using TPA models after frozen storage. They also indicated that tilapia muscle texture gradually declined during frozen storage, however holding at lower temperatures was more conducive to maintaining textural characteristics of tilapia muscle. Luo Sha-Sha, *et al*. [17] studied the effect of high pressure processing on the textural characteristics of *Aristichthys nobilis*. The au-

thors showed that adhesiveness and chewiness of the muscle improved significantly after treatment at 300 millipascals (MPa) or 450 MPa (P<0.05).

The above studies showed that pressure treatment, storage time, storage temperature, and environmental conditions had great influence on the textural characteristics of fish meat (Tab. 4). These studies can provide a theoretical basis for frozen preservation of fish, so as to better prolong the shelf life of fish[18, 19]. However, the effect of different altitudes on the textural characteristics of fish has yet to be reported. This paper marks the first inquiry into textural characteristics of Schizothorax fish from the Yarlung Zangbo River in Shigatse and Nyingchi. We showed that the

Tab. 4 The main factors influencing the textural characteristics of fish

Influential texture factor	Fish species	Collection Site	Textural differences	Literature sources
Aquaculture conditions	*Oplegnathus punctatus*	Two aquaculture models of cage and cement pool	Cage cultured *Oplegnathus punctatus* had better muscle texture and hardness than cement pool	Zhong Hong-Gan, *et al*.[21]
	Paralichthys olivaceus	Wild, pond cultured, factory cultured	Factory cultured *P. olivaceus* showed better water retention, while the physicochemical quality and textural characteristics of pond cultured *P. olivaceus* muscle remained similar to that of the wild *P. olivaceus*	HuPan, *et al*.[22]
	Pagellus bogaraveo	Wild and farmed	Proximal composition showed a higher fat proportion in the farmed group whilst higher collage content was found in the wild group. The fatty acid profile of the farmed group showed important values of EPA and total n-3 HUFA. Sensory evaluation registered changes in all tested features, especially seafood attributes linked to wild fish and fish oil attributed associated with the farmed group	Rincón L, *et al*.[23]
Altitude	*Ptychobarbus dipogon* *Schizothorax macropogon*	The Yarlung Zangbo River in different altitudes of geographical area	Comparing the same Schizothorax fish, hardness, elasticity, cohesion, gumminess, chewiness, doing work at maximum hardness and initial destructive force of *Ptychobarbus dipogon* and *Schizothorax macropogon* from the Yarlung Zangbo River in Shigatse were respectively significantly higher than that of the same fish from the Yarlung Zangbo River in Nyingchi. The results showed that the geographical waters at different altitudes also had a great influence on the textural characteristics of fish	This paper
Pressure	*Aristichthys nobilis*	High pressure processing (150 MPa, 300 MPa and 450 MPa for 15min)	Adhesiveness and chewiness of the muscle improved significantly after treatment at 300 MPa or 450 MPa (P<0.05). High-pressure treatment improved quality of *Aristichthys nobilis* muscle	Luo Sha-Sha, *et al*.[17]
	Trachinotus ovatus	Response surface analysis with Box-Behnken design was used and the sterilization conditions were optimized on the basis of single factor experiment, including pressure, treatment time and temperature	Shearing force, hardness, resilience, springiness, and chewiness improved with increasing pressure	Wang An-Qi, *et al*.[24]
Storage temperature	*Ctenopharyngodon idellus*	Three storage modes: Ice-temperature storage [(–1.5±0.03)℃] Refrigeration [(1±1)℃] Frozen storage [(–18±1)℃]	Compared to frozen storage, ice-temperature storage increased flexibility, adhesiveness and mastication, as well as moderate hardness and shearing force to ensure texture quality	Sun Wei-Qing, *et al*.[25]
	Cyprinus carpio	Ice-temperature (0℃) storage	Hardness, flexibility and chewiness rose at first then decline. Glue viscosity decreased as well	Liu Li-Rong, *et al*.[26]
	Hypophthalmichthys molitrix	Three storage modes: ice temperature (–1.50±0.03)℃, Refrigeration (1±1)℃ frozen (–18±1)℃	Compared with refrigeration and freezing three weeks of ice storage, led to favorable flexibility, cohesiveness, moderate shearing force, and chewiness of silver carp surimi	Sun Wei-Qing, *et al*.[27]
	Pneumatophorus japonicus	90 day' refrigeration at different temperatures (–18℃, –25℃, –35℃)	Muscle texture (hardness, elasticity, cohesiveness) of *Pneumatophorus japonicus* decreased with time in different freezing temperatures, Namely, the lower the freezing temperature, the textural characteristics decreased more slowly	Liang Rui, *et al*.[28]
Storage time	*Oncorhynchus*	Storage at 0℃ for 12 days	Chewiness and hardness of the sample decreased	Zhang Kui, *et al*.[29]
	Pseudosciaena crocea	Storage at different temperatures (–18℃, –50℃) for 50 days	With the extension of the frozen storage period, the textural parameters of cultured *Pseudosciaena crocea* decreased. The hardness, elasticity, chewiness, adhesiveness, cohesiveness, and resilience of *Pseudosciaena crocea* stored at –50℃ were higher than that of *Pseudosciaena crocea* stored at –18℃	Dai Zhi-Yuan, *et al*.[30]
Fermentation	Smelly mandarin fish	Fight days fermentation	Hardness, elasticity, adhesiveness, cohesiveness and chewiness of Smelly Mandarin fish significantly improved through eight days fermentation and Smelly Mandarin fish reached optimum quality	Yang Pei-Zhou, *et al*.[14]

textural characteristics of *Ptychobarbus dipogon* from Yarlung Zangbo River in Nyingchi were different from *Schizothorax macropogon* from Yarlung Zangbo River in Shigatse and Nyingchi and *Ptychobarbus dipogon* from Yarlung Zangbo River in Shigatse. These results demonstrate that locality, and thus potentially altitude had a great influence on the textural characteristics of fish. This research has significance for further developmental research for a series of processing products of Schizothoracinae fishes from the Yarlung Zangbo River. However, sampling season, storage conditions, and time have great influence on textural properties of fish[20]. Therefore, the textural characteristics of Schizothorax fish from the Yarlung Zangbo River in different seasons, different storage conditions, and time should be studied further.

4 Conclusions

Principal component analysis showed that the textural characteristics of *Ptychobarbus dipogon* from Yarlung Zangbo River in Nyingchi were different from *Schizothorax macropogon* from Yarlung Zangbo River in Shigatse and Nyingchi and *Ptychobarbus dipogon* from Yarlung Zangbo River in Shigatse. Comprehensive test analyses of hardness, elasticity, and adhesion showed that species of Schizothorax fish was the main factor in textural differences. At the same time elevation, water temperature, and other hydrological conditions are also important factors in textural differences of Schizothorax fishes. Factorial analysis indicated that the textural characteristics of Schizothoracinae fishes in Tibet autonomous region can be summarized as hardness indices, overcome attraction indices and contractility indices, the cumulative variance contribution of the lead four principal component factors was 81.472%. The three categories of four principal component indices could be the main decision parameters of the textural characteristics of Schizothoracinae fishes in Tibet autonomous region. This research can provide scientific evidence and theoretical bases to develop and utilize Schizothoracinae fishes in Tibet autonomous region.

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西藏两种裂腹鱼鱼肉质构特征比较分析

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摘要: 巨须裂腹鱼*Schizothorax macropogon*和双须叶须鱼*Ptychobarbus dipogon*是雅鲁藏布江特有的重要经济鱼类, 具有多种人体必需脂肪酸, 营养价值高, 但其组织结构和内部性状可直接影响口感。为明确西藏2种裂腹鱼鱼肉的质构特征差异, 保护西藏裂腹鱼资源及其合理开发利用, 采用质地多面剖析法(TPA)分析了西藏雅鲁藏布江日喀则江段和林芝江段的2种裂腹鱼(巨须裂腹鱼、双须叶须鱼)的12项鱼肉质构特征指标, 主成分分析(PCA)表明雅鲁藏布江林芝江段双须叶须鱼鱼肉质构特征较日喀则江段2种裂腹鱼及林芝江段巨须裂腹鱼存在较大差异。析因分析表明可将雅鲁藏布江2种裂腹鱼鱼肉质构特征归纳为硬度、克服鱼肉表面与接触物吸引力及收缩性等3大类4个主成分指标, 前4个主成分累计方差贡献率达81.472%, 可将这3大类4个主成分指标作为雅鲁藏布江裂腹鱼鱼肉质构特征的主要判定参数。研究为后续合理开发利用雅鲁藏布江不同江段的裂腹鱼类提供科学数据。

关键词: 西藏; 雅鲁藏布江; 巨须裂腹鱼; 双须叶须鱼; 质构特征