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TRIVALENT CHROMIUM (Cr^{+3}) IN DIETARY CARBOHYDRATE AND ITS EFFECT ON THE GROWTH OF COMMONLY CULTIVATED FISH

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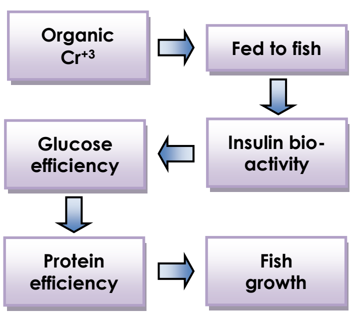
Graphical abstract



Abstract

Trivalent chromium (Cr^{+3}) is an essential trace mineral for fish bio-physiological functions. Researches on Cr^{+3} in the form of organic compound indicated that the mineral affected the bio-activity of insulin, the blood glucose influx, and subsequently the blood glucose metabolic rate. By increasing the blood glucose metabolism, dietary carbohydrate will be more efficiently used as a main energy source, thereby, dietary protein could be efficiently retained as for somatic growth. Researches on various feeding habits of fish (e.g. gouramy-herbivorous fish, tilapia-omnivorous fish, and catfish-carnivorous fish) showed that dietary Cr^{+3} in certain amount increased diet utilization and the fish growth.

Keywords: Blood glucose, chromium, feed, fish, growth

1.0 INTRODUCTION

Trivalent chromium (Cr^{+3}) has been declared since few decades ago as one of the trace-minerals that was essential for human and animals, including fish [1-13]. Researches on the essential mineral, especially in the form of organic compound, indicated that Cr^{+3} played an important role in the bio-activity of insulin, post prandial-blood glucose pattern, dietary carbohydrate-protein utilization, and thereby, growth of the fish [14-22]. Blood glucose pattern of fish fed on diet containing a certain level of chromium were different to each other, depending on the dietary chromium levels and feeding habits of the fish. Herbivorous fish tended to require a lower level of dietary chromium than carnivorous fish [21, 23-25]. Moreover, similar fish species tended to require higher level of chromium when the fish were reared in higher saline water [25]. The present study was carried out to reemphasize the important roles of dietary organic chromium on the post prandial blood glucose pattern, diet utilization efficiency, and growth of various feeding habits of fish. The fish species discussed in this study were gouramy, tilapia, and catfish, each for the herbivorous, omnivorous, and carnivorous fish, respectively.

2.0 BLOOD GLUCOSE PATTERN

Post prandial-blood glucose pattern of three feeding habits of fish were depicted below. The pattern is as final results of the blood glucose influx through blood stream and the blood glucose metabolism rate. Three important points of the blood glucose curve included: i) the curve part from the beginning until the peak level of the curve (i.e. indicating that the blood glucose influx was higher than the blood glucose metabolism rate), ii) the peak level of the curve (i.e. indicating that the blood glucose influx already meets equilibrium to the blood glucose metabolism rate), and iii) the decrease part of the curve after the peak level (i.e. indicating that the blood glucose influx was lower than the blood glucose metabolism rate).

2.1 Blood Glucose Pattern of Herbivorous Fish

The blood glucose patterns of herbivorous fish, gouramy, fed on low (30 %) and high (40 %) dietary carbohydrate, without and with organic chromium, were depicted on Figure 1. It indicated that those blood glucose patterns were affected by dietary carbohydrate, consumed by the fish. It also found that the post prandial blood glucose pattern of fish consumed diets containing chromium showed different patterns to those consumed a diet with no chromium (Figure 1). Moreover, its pattern seems quite different to fish consumed diet containing a certain amount of chromium. Blood glucose was metabolized most quickly (i.e. after 3h-post prandial) by herbivorous fish, gouramy, when dietary chromium of 1.5 ppm (or 1.5 mg $Cr^{+3} \cdot kg^{-1}$ of feed) was fed to the fish. On the other hand, blood glucose of the fish fed on diet without Cr^{+3} tended to be metabolized most slowly (i.e. after 11h-post prandial) (Figure 1), [21].

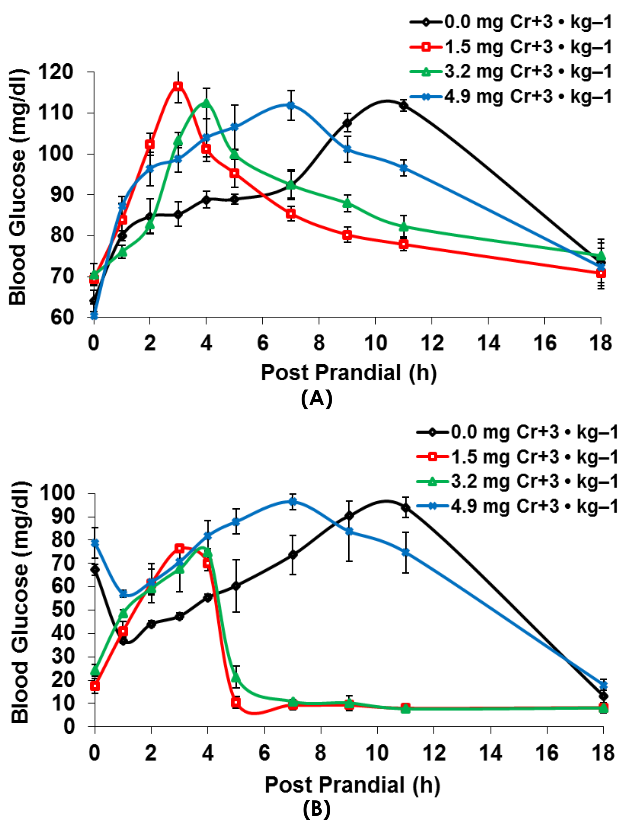


Figure 1 Blood glucose patterns 18 h-post prandial of gouramy (*Osphronemus gouramy*) fed on diets with and without chromium. (A): 30 % of dietary NFE, (B): 40 % of dietary NFE

2.2 Blood Glucose Pattern of Omnivorous Fish

The blood glucose patterns of omnivorous fish, tilapia, fed on diets without and with organic chromium, reared in freshwater and 20 ‰ of saline water, were shown on Figure 2. As shown by gouramy, the blood glucose patterns of tilapia were also affected by dietary chromium consumed by the fish, both for the fish reared in different water salinity levels. In terms of fish reared in freshwater and fed on a diet containing 6.0 ppm of Cr^{+3}, their blood glucose level after 3 h-post prandial decreased faster compared to the others (Figure 2A) [25]. Surprisingly, the blood glucose level of tilapia which was reared in 20 ‰ of saline water fast-decreased at 2 h-post prandial, meaning that was 1 h earlier (Figure 2B), [25]. Those phenomena indicated that dietary chromium in a certain level, and also water salinity, affected the blood glucose metabolism or utilization rate, and therefore, changed its post prandial pattern.

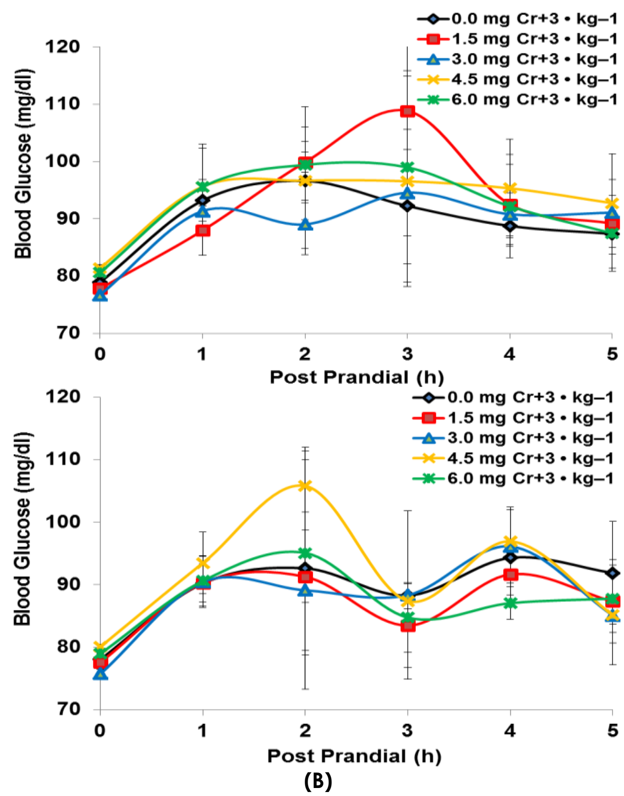


Figure 2 Blood glucose patterns 5 h-postprandial of tilapia (*Oreochromis niloticus*) fed on diets with and without chromium. (A): reared in freshwater; (B): reared in 20 ‰ of saline water

2.3 Blood Glucose Pattern of Carnivorous Fish

Figure 3 showed the blood glucose pattern of carnivorous fish, catfish (*Clarias gariepinus*) fed on diets without and with dietary Cr^{+3} [23]. In terms of the fish fed on a diet containing chromium of 6.0 mg $Cr^{+3} \cdot kg^{-1}$, its blood glucose level after 3 h-post prandial decreased faster compared to the others. As well as shown on Figure 1, the blood glucose level of fish fed on dietary Cr^{+3} fast increased just after feeding. It indicated that dietary carbohydrate was hydrolyzed effectively and then was transported quickly to the blood stream. Conversely, the fish fed on dietary chromium of 0.0 mg $Cr^{+3} \cdot kg^{-1}$ has already acclimated to a high blood glucose level (Figure 3), [23-24]. Therefore on the fasting state (0 h-post prandial), gluconeogenesis might occur; and moreover on the onset of feeding (1 h-post prandial), whenever a lack of glucose supply from diet to the blood stream occurred, the blood glucose level decreased, as well.

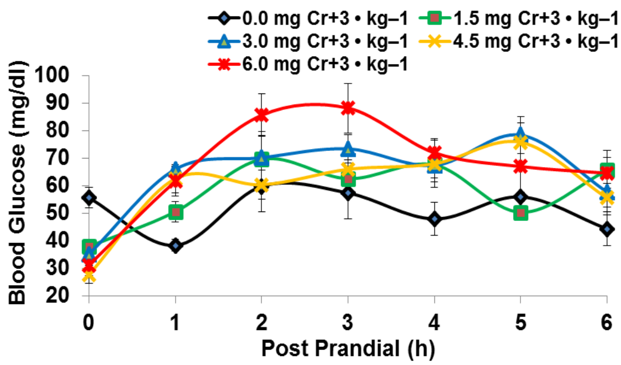


Figure 3 Blood glucose patterns 6 h-postprandial of catfish (*Clarias gariepinus*) fed on diets with and without chromium

3.0 DIET UTILIZATIONS

Diet utilization efficiency of feeds was indicated by the values of several bio-physiological aspects, such as macro nutrient retention, energy retention, feed efficiency, and growth of fish. Most of fish utilized diet more efficiently when chromium was added to the feed. The optimum level of chromium required by fish with different feeding habits and water salinity were slightly different. However in the case of gouramy, the fish fed on diet containing higher level of carbohydrate required similar level of chromium.

3.1 Macro Nutrient and Energy Retention

Macro nutrient and energy retention of diets fed to various feeding habits of fish were depicted on Table 1.

3.2 Feed Efficiency and Fish Growth

The feed efficiency and growth values of fish fed on diets without and with chromium were depicted on Table 2. In general, bio-physiological aspects of various feeding habits of fish were affected after the fish consumed dietary Cr^{+3} (Table 1, 2). Fed efficiency and the growth of fish found increasing after feeding dietary Cr^{+3} (Table 2). However, similar growth was found for catfish.

Table 1 Some bio-physiological aspects of various feeding habits of fish, after feeding without and with dietary chromium

Bio-physiological aspects	Fish species	Without chromium*)	With chromium*)	Feeding habit	References
Low NFE diet (30 %)	Gouramy			Herbivorous	[21]
Protein retention (%)		32.6 ± 1.0^{a}	35.8 ± 3.5^{a}		
Fat retention (%)		84.9 ± 5.1^{a}	80.9 ± 7.9^{a}		
Energy retention (%)		38.7 ± 1.0^{a}	39.6 ± 2.6^{a}		
High NFE diet (40 %)	Gouramy			Herbivorous	[19]
Protein retention (%)		38.2 ± 0.6^{a}	41.0 ± 2.7^{a}		
Fat retention (%)		121.1 ± 4.9^{a}	128.8 ± 2.2^{a}		
Energy retention (%)		40.9 ± 1.3^{a}	42.5 ± 2.0^{a}		
Freshwater	Tilapia			Omnivorous	[25]
Protein retention (%)		71,26	78,9		
Fat retention (%)		43,20	83,38		
Energy retention (%)		34,10	39,20		
20 ‰ saline water	Tilapia			Omnivorous	[25]
Protein retention (%)		57,40	58,86		
Fat retention (%)		63,78	84,49		
Energy retention (%)		44,90	48,70		
Freshwater	Catfish			Carnivorous	
Protein retention (%)		54,46±0,99^{a}	57,35±0,11^{b}		[26]
Fat retention (%)		98,83±1,79^{b}	75,51±1,76^{a}		
Protein efficiency ratio (%)		312,7±5,79^{a}	325,9±0,9^{b}		[27]

Note : Value ± se
Gouramy (*Osphronemus goramy* Lacepède, 1801), Tilapia (*Oreochromis niloticus* Linnaeus, 1758), Catfish (Clarias gariepinus Burchell, 1822).

Table 2 Feed efficiency and growth of various feeding habits of fish, after rearing and feeding without and with dietary chromium

Bio-physiological aspects	Fish species	Without chromium	With chromium	Feeding habit	References
Low NFE diet (30 %)	Gouramy			Herbivorous	[21]
Feed efficiency (%)		67.3 ± 0.9^a	73.2 ± 0.2^b		
Relative growth (%)		193.9 ± 3.4^a	254.9 ± 4.8^b		
High NFE diet (40 %)	Gouramy			Herbivorous	[19]
Feed efficiency (%)		75.8 ± 0.2^a	78.3 ± 0.6^b		
Relative growth (%)		236.5 ± 14.0^a	270.9 ± 4.8^b		
Freshwater	Tilapia			Omnivorous	[25]
Feed efficiency (%)		53,67 ± 5,13^a	82,67 ± 3,06^b		
Relative growth (%)		147,67 ± 5,86^a	204,67 ± 21,94^b		
20 ‰ of saline water	Tilapia			Omnivorous	[25]
Feed efficiency (%)		62,67 ± 8,33^a	92,67 ± 8,08^b		
Relative growth (%)		132,33 ± 13,05^a	200,67 ± 29,50^b		
Freshwater	Catfish			Carnivorous	[27]
Feed efficiency (%)		118,33 ± 2.08^a	122,67 ± 1,53^b		
Relative growth (%)		969,63 ± 34,97^a	1046,38 ±72,01^a		

Note : Value ± se
Gouramy (*Osphronemus goramy* Lacepède, 1801), Tilapia (*Oreochromis niloticus* Linnaeus, 1758), Catfish (Clarias gariepinus Burchell, 1822)

4.0 CONCLUSION

This finding proved that: i) Organic chromium (Cr^{+3}) fed to fish affected blood glucose metabolism, and therefore, the post-prandial blood glucose pattern of the fish changed; ii) Lack of Cr^{+3} prolonged the peak level of blood glucose; iii) Either lack or excess of Cr^{+3} retarded or decreased the fish growth. However, the optimum requirement of Cr^{+3} varied between in a narrow range; and iv) The same species of fish required higher level of dietary Cr^{+3} when the fish was fed on higher dietary NFE level or reared in a higher salinity of waters.

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