• Volume 8 • Number 1 • January-June 2018

Print ISSN 2319-2186
Online ISSN 2322-0996
www.biotechtoday.co.in

Society of Green World for Sustainable Environment

International Journal of Biological Sciences

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Biotech Today (January-June 2018) 8(1) : 76-87

DOI : 10.5958/2322-0996.2018.00011.X

RESEARCH ARTICLE

Seasonal Variation of amino acids and fatty acids in the liver of *Labeo rohita*

Sangeeta* and Kamana Sharma

Received : 8 September 2017, **Revised :** 8 October 201 **Accepted :** 22 October 2018, **Published :** online 2 January 2018.

Abstract

The protein quality of food protein depends on its digestibility and its ability to provide all essential amino acids and polyunsaturated fatty acids (ω-3). The composition of fatty acid, protein and amino acids of fish are influenced by intrinsic and extrinsic factors like species, size, sexual maturity, food resources, fishing season, water salinity and temperature. The present study is aimed to find out seasonal variations in polyunsaturated fatty acid (ω-3), essential and non-essential amino acids in the liver of a local fresh water fish *Labeo rohita*. The seasonal categories used for the present study were,Winter, Pre-monsoon, Monsoon and Post-monsoon. It was observed that among the essential amino acids, the level of Phenylalanine, Lysine, Leucine, Arginine, Valine, Isoleucine, Histidine, Methionine and Tryptophan were at their highest level in monsoon season while the level of Valine and Isoleucine were at maximum level in pre-monsoon season but the level of Threonine was highest in winter season. Among the non-essential amino acid, the level of Glutamic acid, Aspartic acid, Tyrosine, Alanine, Proline and Serine were maximum in monsoon season while the level of Cysteine was maximum in post-monsoon season ω-3 polyunsaturated fatty acid was highest in monsoon season.

Key word: Seasonal fluctuations, Essential and non essential amino acids, ω-3 fatty acid, *Labeo rohita*

Introduction

Fish is one of the main food constituents in the human diet as it includes essential fatty acids, amino acids and some of the principal vitamins and minerals in sufficient amounts for healthy living (Borgstrom, 1961). Fish is widely consumed in many parts of the world because it is high in protein and low in saturated fat. It is an excellent dietary sources of highly unsaturated fatty acid (HUFA) and polyunsaturated fatty acid (PUFA), especially the omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid, (DHA) (Huynh *et. al*. 2007). Experimental studies indicate that ω-3 polyunsaturated fatty acids (PUFA) have a beneficial effect on coronary heart disease, primary and secondary prevention of atherosclerosis, thrombosis, blood pressure, embolic phenomenon, inflammation, cancer, depression, hypertriglyceridemia, hypertension, skin disorders, autoimmune disease, and possibly allergy (Kucukgulmez *et al*. 2010). Generally, fish is an excellent source of protein, because of the amino acid composition and degree of digestibility (Louka *et al.,* 2004). Fish as a whole has a lot of food potential because it provides superior quality protein, well balanced essential amino acids and relief from malnutrition. (Hossain, 1996). In addition to that fish flesh is tasty and highly digestible and it increases life expectancy (Barlas, 1986). Today, there is increasing interest in fish consumption because of their high PUFA content which is linked to health benefits such as decreased incidence of breast cancer, rheumatoid arthritis, multiple scelerosis, asthma, psoriasis, inflammatory bowel disease (Simopoulos 2002, JHCI UK 2004) and regulation of prostaglandin synthesis (Gibson 1983). Essential amino acids cannot be synthesized by the organism so must be consumed via food. The essential amino acids include Isoleucine, Leucine, Lysine, Methionine, Phenylalanine, Threonine, Tryptophan and Valine, Arginine and Histidine. Arginine is conditionally essential amino acid. They are the critical component of proteins in the fish body, which help to increase the growth rate. In addition, fish oil is a rich source of vitamins including vitamin A, D, E, and K, which are soluble in oil and must be taken on a regular basis because of their key roles in human health and metabolism (Kinsella, 1987). Cereal proteins are usually low in lysine or the sulphur-containing amino acids like methionine and cysteine, whereas fish protein is an excellent source of these amino acids. Fish is also rich in the non-protein amino acid taurine, which has a unique role in

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neurotransmission. The composition of nutrient varies greatly from species to species and also from individual to individual depending on age, sex, environment and season (Huss, 1988; 1995). Furthermore, the variations in proximate composition of fish are closely related to the feed intake. During periods of heavy feeding, the protein content of muscle tissue increases slightly at first and then the fat content might show a marked and rapid increase. On the other hand, fish may have starvation periods for natural or physiological reasons (spawning or migration) or because of external factors such as shortage of food. In that case, fat content gradually decreases and then a decline in protein may also be seen (Huss, 1988; 1995).

Material and Methods

For the present study, fishes were obtained from the local market of Meerut region .Fishes were identified using DAY'S Fauna (1889) and Fishes of U.P. and Bihar by Gopal Ji Srivastava (2014). Immediately after collection these fishes were washed and taken into the laboratory. Body of specimen were made free from skin and scales and dissected from the anal pore for taking out the liver. The fish liver was gutted, washed, filleted, minced and homogenized in a homogeniser and immediately used for the estimation of different component.

Estimation of Amino acid

For the estimation of the amino acids, the liver was first hydrolysed. The free amino acids were extracted from the tissue in ethanol according to Dimova (2003) and Gheslaghi *et. al*., (2008) using the high performance liquid chromatography (HPLC) method. This method is based on the reading of ultra fast liquid chromatography-ultravoilet (UFLC-UV) detector by derivatization with phenyl-isothiocyanate and acetonitrile: methanol: triethylamine solution after acidic hydrolysis applied to disassociate the constitute proteins into amino acid component. The amino acids were determined by High performance liquid chromatography techniques (Ishida *et. al*. 1981).

The amino acids estimated were as follows:

Essential amino acids: Phenylalanine, Valine, Tryptophan, Threonine, Isoleucine, Methionine, Histidine, Arginine, Leucine and Lysine while arginine is a conditionally essential amino acid.

Non essential amino acid: Glutamic acid, Aspartic acid, Tyrosine, Glycine, Alanine, Proline, Serine and Cysteine

A comparison of the nutritive value of the above fish was made season wise. Season wise they were categorised into Pre-monsoon season, Monsoon season, Post-monsoon season and winter season.

Estimation of ω- fatty acid: For the estimation of ω-fatty acids ten gram of each homogenized sample was used for fatty acid analysis. Lipid was extracted by using toluene and methanol 2:1 (v/v) (Folch *et al*. 1957 and Bligh *et al*. 1959). Bf_3 and n- hexane was used for the preparation of the fatty acid methyl esters (FAME) (Metcalfe *et al*. 1966). Fatty acids was identified by Gas Liquid Chromatography (GLC) (Nucon 5765, Supelco 2560).

Table 1 : Seasonal variation of Essential Amino acids in the Liver of *Labeo rohita*. Data is expressed as arithmatical mean and standard deviation (SD).

Amino Acids	Winter	Pre-monsoon	Monsoon	Post-monsoon
Phenyl alanine	1111.58 ± 1.51	1315.56 ± 3.10	1514.28 ± 100.53	1015.17 ± 6.08
Lysine	1011.86 ± 2.54	1084.57 ± 60.59	1517.54 ± 2.67	917.98 ± 4.53
Leucine	991.54 ± 2.02	1017.83 ± 3.48	1088.53 ± 52.82	991.23 ± 6.68
Arginine	911.05 ±1.52	1019.66 ± 4.58	1202.83 ± 57.20	814.44 ± 5.17
Valine	610.75 ± 1.02	719.82 ± 3.05	617.91 ± 3.62	516.43 ± 2.56
Isoleucine	168.28 ± 2.09	273.57 ± 4.14	258.6 ± 4.47	159.84 ± 3.86
Histidine	120.9 ± 1.51	131.89 ± 4.02	204.79 ± 5.72	108.02 ± 4.07
Methionine	101.4 ± 1.52	132.15 ± 3.75	202.09 ± 4.75	99.75 ± 3.98
Tryptophan	70.21±2.06	81.55 ± 3.02	95.93 ± 2.66	70.88 ± 4.69
Threonine	63.92 ±2.51	62.36 ± 2.65	61.70 ± 4.02	36.91 ± 4.16

Statistical analysis

The results obtained were analyzed statistically by performing R software and student t-tests. Significance level was set to an alpha level of 0.05 (Sokal and Rolf, 1974). The level of significance were expressed as p value less or greater than 0.05.

Results and Observations

The data obtained after the study is given in the Table 1 (essential amino acids), Table 2 (non essential amino acids) and Table-3 (ω-3 Fatty acid) in all the four seasons: winter, pre-monsoon, monsoon and post-monsoon.

Changes in the level of amino acid in liver of *Labeo rohita*

Phenyl-alanine: The level of phenyl-alanine was greatly increased in pre-monsoon and monsoon and significantly decreased in winter and post- monsoon.

Lysine: The value of lysine was significantly increased in monsoon, considerably decreased in winter and pre-monsoon but it was highly decreased in post-monsoon season.

Leucine: The level of leucine was considerably increased in pre-monsoon and monsoon season but it was slightly decreased but remains unchanged in winter and post-monsoon season.

Arginine: The level of arginine was significantly increased in pre-monsoon and monsoon season and greatly decreased in winter and post-monsoon season.

Valine: The value of valine was significantly increased in pre-monsoon season, moderately decreased in monsoon and winter but it was significantly decreases in post-monsoon season.

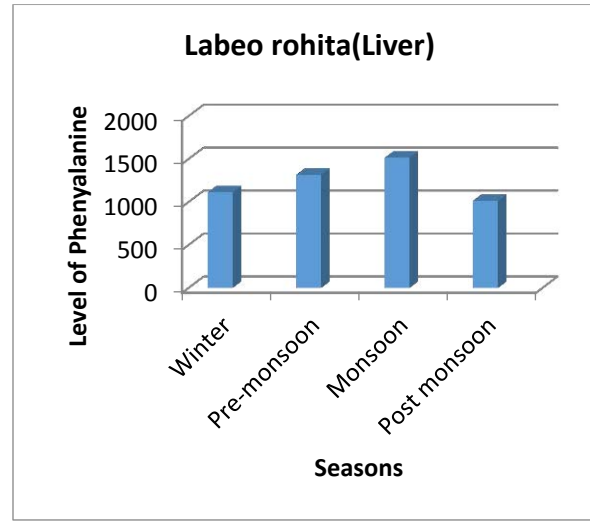
Isoleucine: The level of isoleucine was greatly increased in pre-monsoon and monsoon season but it was considerably decreased in winter and post-monsoon season.

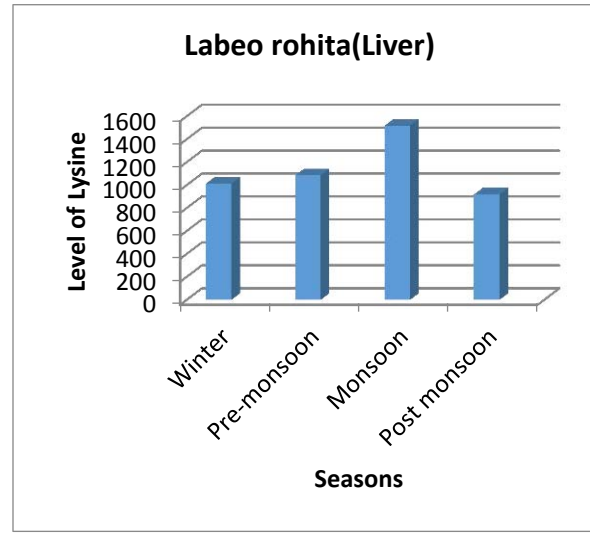
Histidine: The value of histidine was significantly increased in monsoon, moderately decreased in pre-monsoon and winter but it was highly decreased in post-monsoon season.

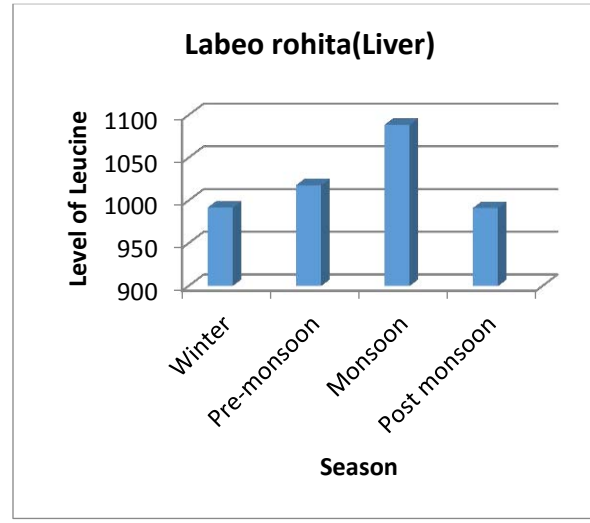
Methionine: The level of methionine was greatly increased in monsoon, slightly decreased in pre-monsoon and moderately decreased in winter and post-monsoon season.

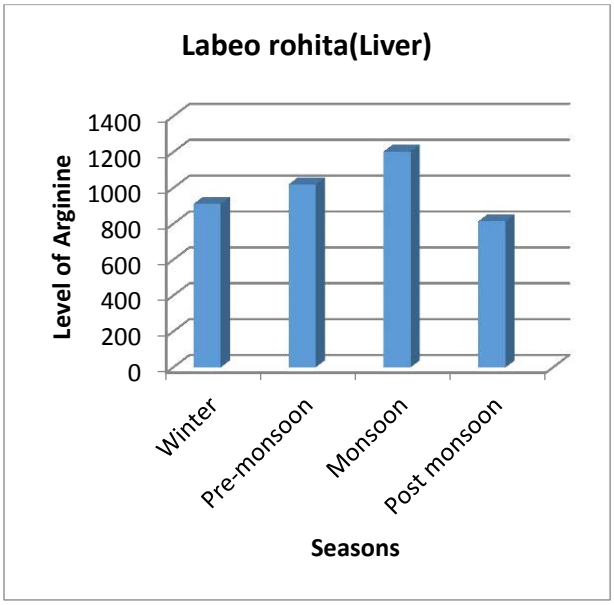
Tryptophan: The value of tryptophan was considerably increased in monsoon slightly decreased in pre-monsoon season, and moderately decreased but remain unchanged in winter and post-monsoon season.

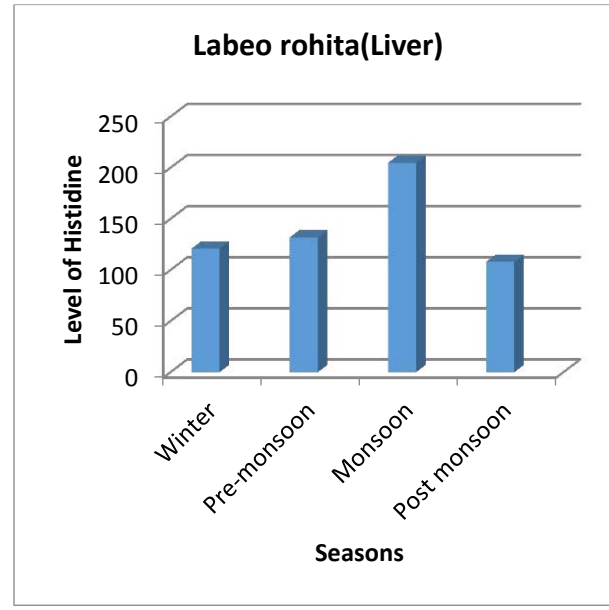
Threonine: The level of threonine was slightly increased in winter and slightly decreased in pre-monsoon and monsoon but it was highly decreased in post-monsoon season.

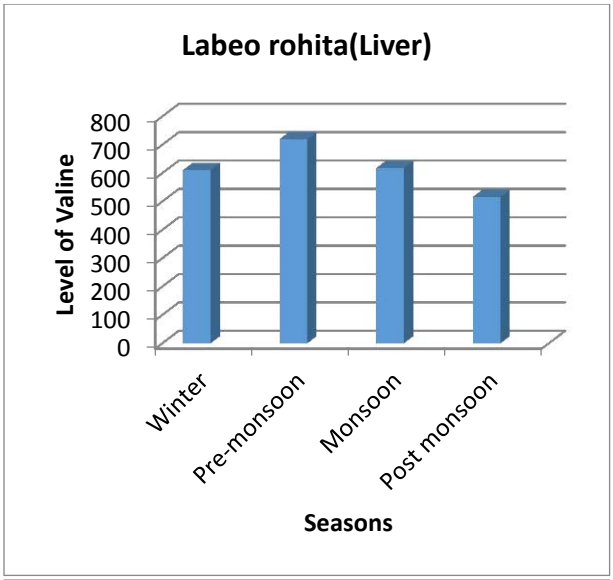


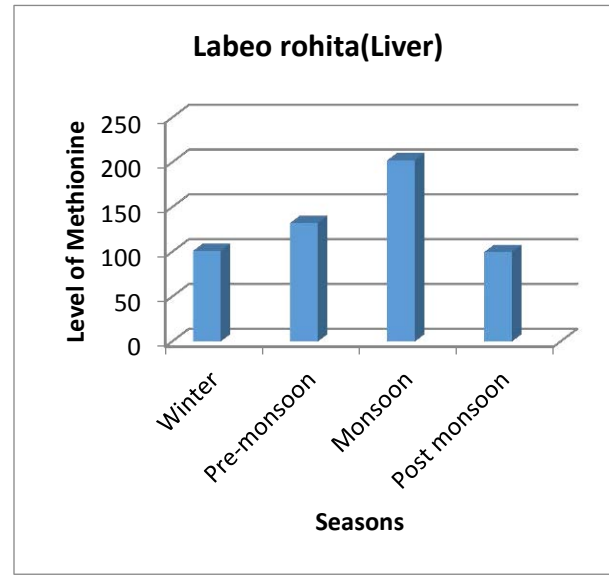


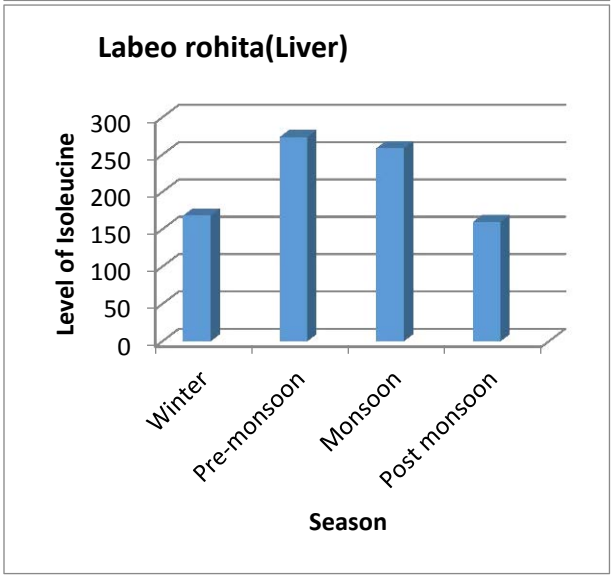


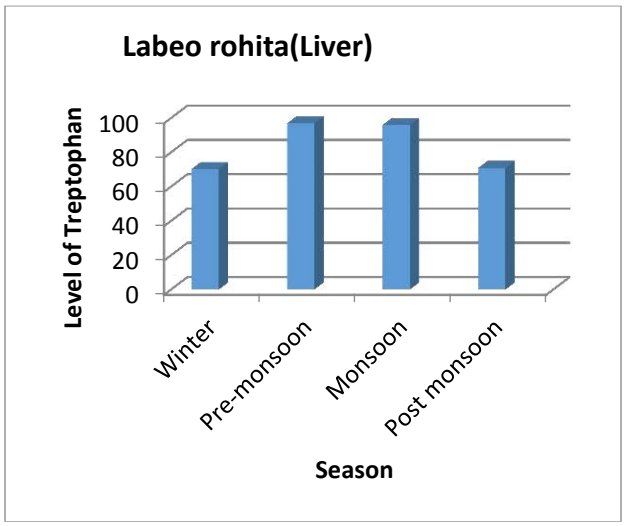

Labeo rohita(Liver)
Level of Arginine
1400
1200
1000
800
600
400
200
0
Winter
Pre-monsoon
Monsoon
Post monsoon
Seasons


Labeo rohita(Liver)
Level of Histidine
250
200
150
100
50
0
Winter
Pre-monsoon
Monsoon
Post monsoon
Seasons


Labeo rohita(Liver)
Level of Valine
800
700
600
500
400
300
200
100
0
Winter
Pre-monsoon
Monsoon
Post monsoon
Seasons


Labeo rohita(Liver)
Level of Methionine
250
200
150
100
50
0
Winter
Pre-monsoon
Monsoon
Post monsoon
Seasons


Labeo rohita(Liver)
Level of Isoleucine
300
250
200
150
100
50
0
Winter
Pre-monsoon
Monsoon
Post monsoon
Season



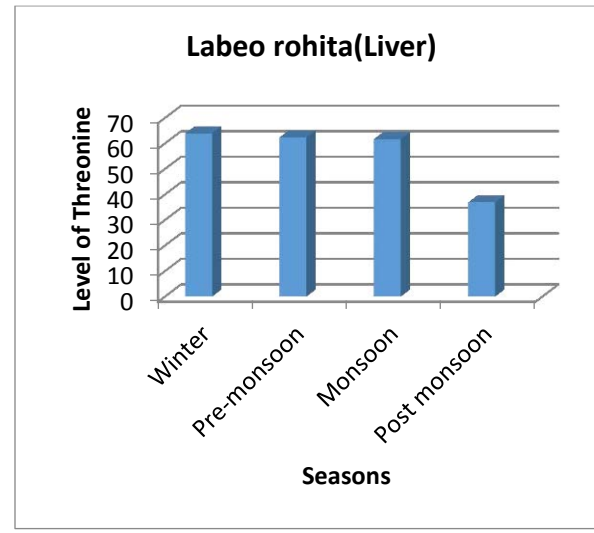


Table 2: Seasonal variation of non-essential amino acids in the liver of *Labeo rohita*. Data is expressed as arithmetical mean and standard deviation (SD).

Amino Acids	Winter	Pre-monsoon	Monsoon	Post-monsoon
Glutamic Acid	2391.16 ±1.55	2593.24 ± 6.07	3061.27 ± 151.30	2117.41 ± 56.88
Aspartic acid	2051.59 ± 2.08	2252.95 ± 5.30	2561.52 ± 96.12	1965.65 ± 8.88
Tyrosine	1058.73 ± 3.77	1258.43 ± 4.55	1582.21 ± 55.18	1068.14 ± 3.08
Glycine	930.95 ± 1.51	931.94 ± 3.03	1036.06 ± 3.05	932.32 ± 3.54
Alanine	851.47 ± 2.06	953.48 ± 4.72	1014.91 ± 2.54	837.22 ± 4.59
Proline	766.22 ± 2.67	878.6 ± 4.09	987.66 ± 3.21	759.59 ± 3.81
Serine	316.97 ± 1.51	519.29 ± 4.96	616.65 ± 3.54	316.98 ± 5.13
Cysteine	60.63 ±1.54	68.91 ± 2.98	78.6 ± 8.08	85.29 ± 2.49

Changes in the level of non-essential amino acid in Muscle of *Labeo rohita*:

Glutamic acid: The level of Glutamic acid was greatly increased in monsoon, considerably decreased in pre-monsoon and winter but it was highly decreased in post-monsoon season.

Aspartic acid: The level of aspartic acid was significantly increased in monsoon, moderately decreased in pre-monsoon season, considerably decreased in winter but it was highly decreased in post-monsoon season.

Tyrosine: The level of tyrosine was highly increased in monsoon, moderately decreased in pre-monsoon but highly decreased in post-monsoon and winter season.

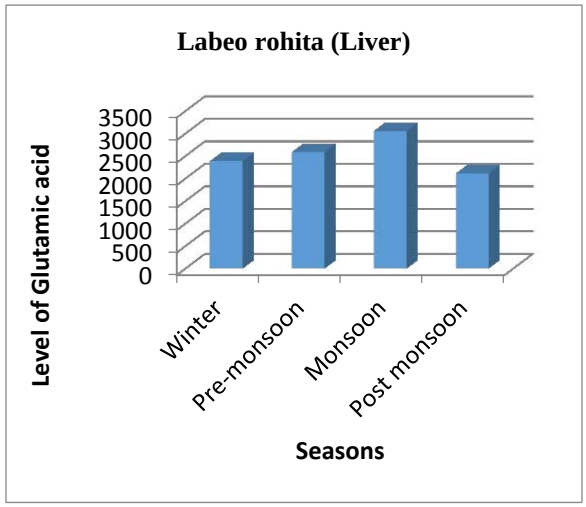
Glycine: The value of glycine was moderately increased in monsoon and slightly decreased in other seasons.

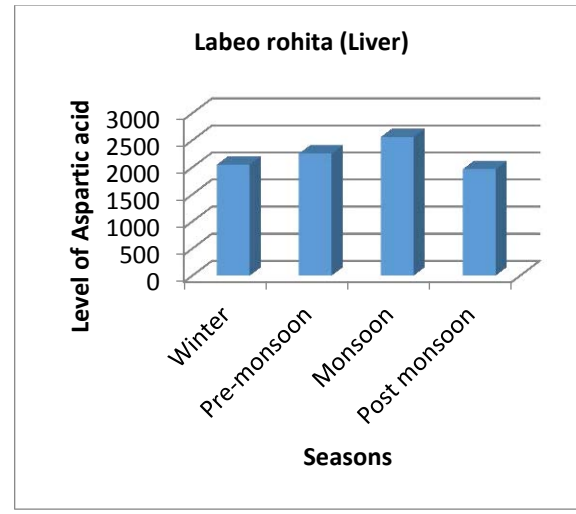
Alanine: The level of alanine was significantly increased in monsoon, slightly decreased in pre-monsoon but it was considerably decreased in winter and post-monsoon season.

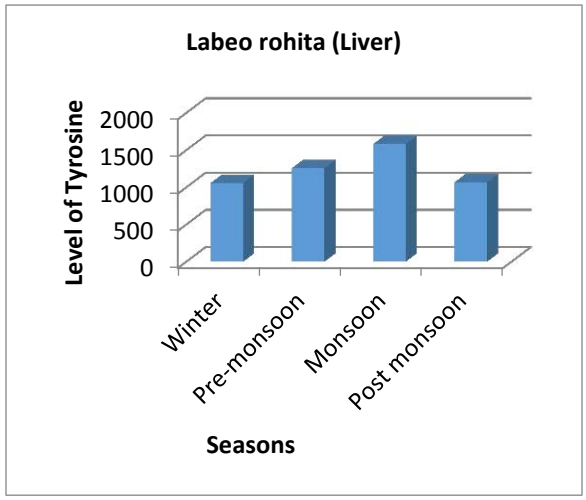
Proline: The value of proline was greatly increased in monsoon season moderately decreased in pre-monsoon but it was considerably decreased in winter and post-monsoon season.

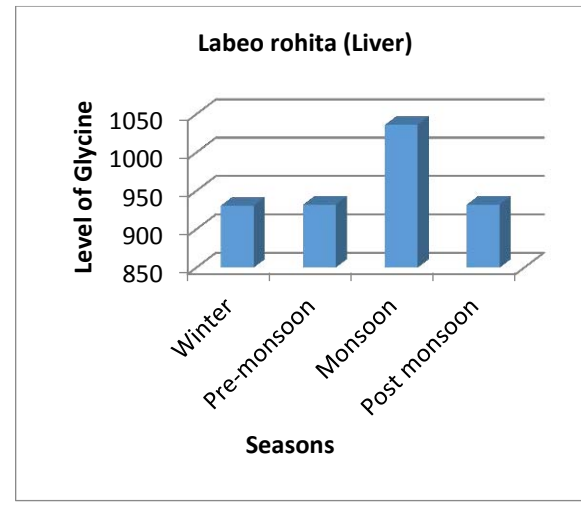
Serine: The value of serine was highly increased in monsoon, moderately decreased in pre-monsoon, considerably decreased but remains unchanged in winter and post-monsoon season.

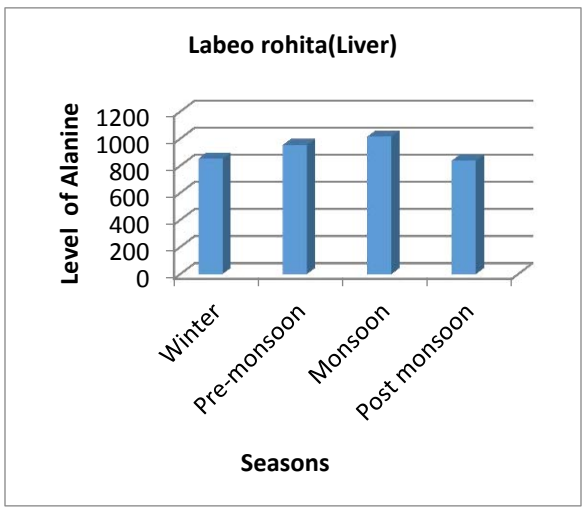
Cysteine: The level of cysteine was highly increased in post-monsoon, slightly decreased in monsoon and pre-monsoon while it was significantly decreased in winter season.

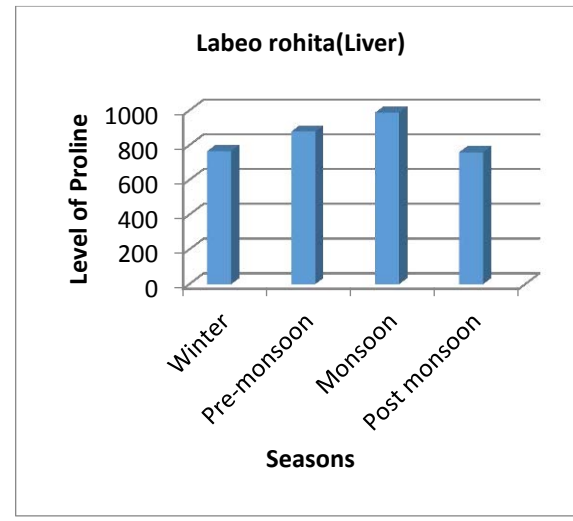

Labeo rohita (Liver)
Level of Glutamic acid
3500
3000
2500
2000
1500
1000
500
0
Winter
Pre-monsoon
Monsoon
Post monsoon
Seasons

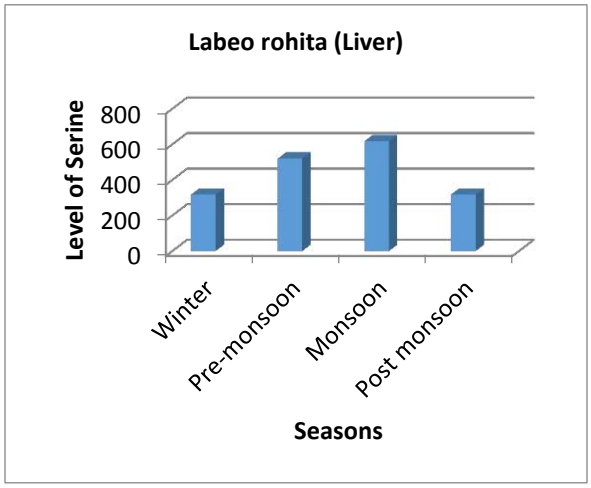

Labeo rohita (Liver)
Level of Aspartic acid
3000
2500
2000
1500
1000
500
0
Winter
Pre-monsoon
Monsoon
Post monsoon
Seasons


Labeo rohita (Liver)
Level of Tyrosine
2000
1500
1000
500
0
Winter
Pre-monsoon
Monsoon
Post monsoon
Seasons


Labeo rohita (Liver)
Level of Glycine
1050
1000
950
900
850
Winter
Pre-monsoon
Monsoon
Post monsoon
Seasons


Labeo rohita(Liver)
Level of Alanine
1200
1000
800
600
400
200
0
Winter
Pre-monsoon
Monsoon
Post monsoon
Seasons


Labeo rohita(Liver)
Level of Proline
1000
800
600
400
200
0
Winter
Pre-monsoon
Monsoon
Post monsoon
Seasons



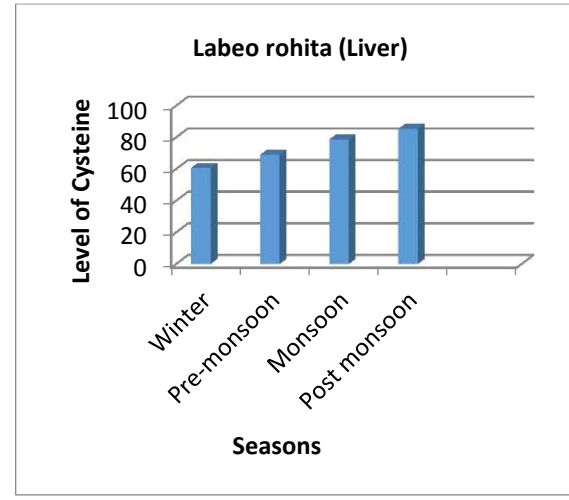
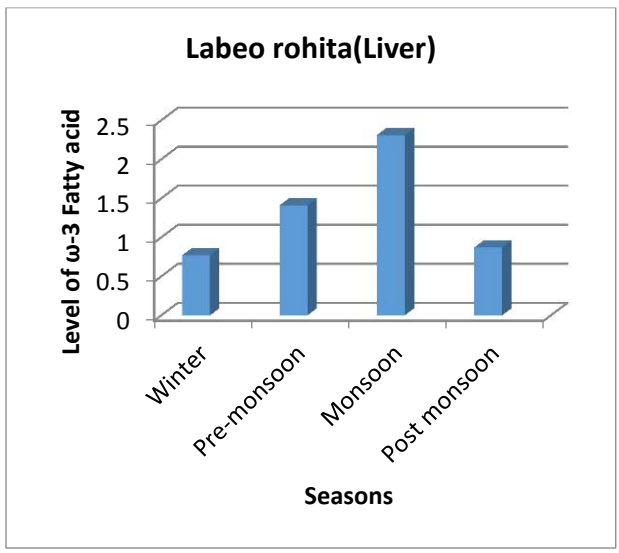


Table 3: **Seasonal variation of essential fatty acids (ω-3 PUFA) in the Liver of *Labeo rohita*. Data is expressed as arithmetical mean and standard deviation (SD).**

	Winter	Pre-monsoon	Monsoon	Post-monsoon
ω-3 fatty acid	0.77 ± 0.02	1.41 ± 0.02	2.31 ± 0.04	0.87 ± 0.02

Changes in the level of fatty acid in Liver of *Labeo rohita*

ω-3 fatty acid: The level of ω--3 fatty acid was intensively increased in monsoon, moderately decreased in pre-monsoon while it was considerably decreased in post-monsoon and winter season.



Discussion

In the present study, the level of essential, non essential amino acid and ω-fatty acid was first observed in winter season and the comparative changes were observed in pre-monsoon, monsoon and post-monsoon season. It was found that except few amino acids there was an overall increase in most of the amino acid in monsoon season.

In our study the level of phenylalanine in the liver of *Labeo rohita* was highly increased in monsoon, moderately decreased in pre-monsoon but it was significantly decreased in winter and post-monsoon season. Hwang *et. al*. (2014) observed the seasonal variation in the chemical composition of yellow sea bream (*Dentex tumifrons*) and observed that the value of phenylalanine was significantly increased in winter, slightly decreased in monsoon and post-monsoon season but it was considerably decreased in pre-monsoon season. Phenylalanine is an essential aromatic amino acid in human which can be provided by food, it plays a key role in the biosynthesis of other amino acids and is important in the structure and function of many proteins and enzymes. Phenylalanine also elevates mood, decrease pain, aid in memory and learning and suppress the appetite. Phenylalanine serves as a precursor for synthesis of tyrosine (Fernstrom and Fernstrom 2007). It can also be used to treat arthritis depression, migraines, obesity etc.

Level of lysine in the liver of fish was highly increased in monsoon, considerably decreased in pre-monsoon and winter but it was highly decreased in post-monsoon season. Dogan and Ertan (2017) observed the amino acid composition of goldband goatfish (*Upeneus moluccensis*) and concluded that the level of lysine was significantly increased in winter but considerably decreased in post-monsoon and pre-monsoon season. Lysine is required for optimal growth and its deficiency leads to

immunodeficiency (Chen *et al.,* 2003). Lysine is concentrated in muscle tissue, helps in the absorption of calcium from the intestinal tract for the promotion of bone growth and helps our body to produce collagen.

In our study the level of leucine was considerably increased in monsoon, slightly decreased in pre-monsoon while it was moderately decreased, but remain unchanged in winter and post-monsoon season. Yildiz and Mensah (2017) made a study on seasonal variation on fillet amino acid profile of sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) and compared the level of leucine, it was moderately increased in summer season and slightly decreased in winter season in *Sparus aurata* but the level of leucine was significantly increased in summer and moderately decreased in winter season in *Dicentrarchus labrax*. Leucine increases the synthesis of muscle proteins (Etzel, 2004). Leucine also helps in regulating the blood sugar levels, promotes the growth and the recovery of muscle and bone tissues, as well as the production of the growth hormone. It has important therapeutic role in stress conditions like burn, trauma, and sepsis (Bandt and Cynober, 2006). Arginine is a conditionally essential amino acid while the level of arginine in the liver of fish was considerably increased in monsoon, moderately decreased in pre-monsoon, considerably decreased in winter but it was highly decreased in post-monsoon season. Caglak and Karsali (2017) studied on seasonal variation of amino acid composition in the muscle tissue of Zander (*Sander lucioperca*) and reported that the level of arginine was significantly increased in autumn, slightly decreased in winter season but it was considerably decreased in summer and spring season. Arginine plays an important role in cell division, wound healing, immune function blood clotting, and maintenance of blood pressure (Mohanty *et al*, 2014). In the body, arginine changes into nitric oxide. Nitric oxide is a powerful neurotransmitter that helps blood vessels relax and also improves circulation. Arginine also helps to improve blood flow in the arteries of the heart.

The level of valine in the liver of fish was considerably increased in pre-monsoon, slightly decreased in monsoon and winter but it was highly decreased in post-monsoon season. Deka *et. al*., (2012) working on seasonal variation of essential amino acid contents in the liver of *Labeo gonius* observed the level of valine significantly increased in pre-monsoon, slightly decreased in monsoon, moderately decreased in winter but it was highly decreased in post-monsoon season under lotic water body but in lentic water body the level of valine significantly increased in pre-monsoon, slightly decreased in winter, considerably decreased in monsoon but it was highly decreased in post-monsoon season. Valine has a stimulant effect and is needed for muscle metabolism, tissue repair and maintenance of a proper nitrogen balance in the body. Valine is a branched chain amino acid, it works with other two branched chain amino acid, isoleucine and leucine to promote normal growth, tissue repair, regulate blood sugar and provide the body with energy.

The value of isoleucine in the liver of *Labeo rohita* was considerably increased in pre-monsoon slightly decreased in monsoon season while it was highly decreased in winter and post-monsoon season. Ozyurt and Polat (2006) studied seasonal differentiation and amino acid composition of wild sea bass (*Dicentrarchus labrax*) and observed that the level of isoleucine was considerably increased in winter, slightly decreased in spring and autumn while it was moderately decreased in summer season . Isoleucine is a branched chain amino acid and is needed for muscle formation and proper growth (Charlton, 2006). It is also used in the body to produce certain biochemical compounds that help in energy production to boost up the energy levels and to assist the body in recovering from strenuous physical activity.

The level of histidine in the liver of our fish considerably increased in monsoon, moderately decreased in pre-monsoon while it was highly decreased in winter and post-monsoon season. Effong *et. al*. (2008) worked on seasonal variation on the nutrient composition in selected fish species and observed that the value of histidine was considerably increased in monsoon season but it was slightly decreased in pre-monsoon season. Histidine plays multiple roles in protein interaction (Liao *et. al*, 2013) and is also a precursor of histamine. It is also needed for growth and repair of tissue, for maintenance of the myelin sheaths, and in removing heavy metals from the body (Heimann, 1982).

The level of methionine in the liver of fish was considerably increased in monsoon, moderately decreased in pre-monsoon but it was highly decreased in winter and post-monsoon season. Chakraborty *et. al*., (2014) worked on seasonal dynamics of amino acid of ribbon fish (*Trichiurus lepturus*) and reported that the level of methionine was significantly increased in monsoon, slightly decreased in post-monsoon season but considerably decreased in pre-monsoon season in south west coast

of India and different alteration was seen in south east coast of India, the level of methionine was considerably increased in post-monsoon, moderately decreased in monsoon but highly decreased in post-monsoon. Methionine is used for treating liver disorders, improving wound healing, and treating depression, alcoholism, allergies, asthma, copper poisoning, radiation side effects, schizophrenia, drug withdrawal, and Parkinson's disease (Mischoulon and Fava, 2002).

The level of tryptophan moderately increased in monsoon, slightly decreased in pre-monsoon while it was moderately decreased but remain unchanged in winter and post-monsoon season. Yildiz and Mensah (2017) experimented on seasonal variation on fillet amino acid profile of sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) and compared the level of tryptophan, it was moderately increased in summer season and slightly decreased in winter season in *Sparus aurata* but the level of tryptophan was significantly increased in winter and moderately decreased in summer season in *Dicentrarchus labrax* . Tryptophan is a precursor for serotonin, a brain neurotransmitter theorized to suppress pain. Free tryptophan enters the brain cells to form serotonin. Tryptophan supplement is used in treatment of pain, insomnia, depression, seasonal affective disorder, bulimia, premenstrual dysphoric disorder, attention deficit, hyperactivity disorder, and chronic fatigue (Richard, 2009).

The value of threonine was slightly increased in winter, slightly decreased in pre-monsoon and monsoon but it was highly decreased in post-monsoon season. Hwang *et. al.*, (2014) explored seasonal variation in the chemical composition of yellow sea bream (*Dentex tumifrons*) and observed that the value of threonine was significantly increased in winter, slightly decreased in monsoon and post-monsoon season but it was considerably decreased in pre-monsoon season. Threonine is used for treating various nervous system disorders including spinal spasticity, multiple sclerosis, familial spastic paraparesis, and amyotrophic lateral sclerosis (Hyland, 2007).

Among the non-essential amino acid the level of glutamic acid in the liver of *Labeo rohita* was significantly increased in monsoon, considerably decreased in pre-monsoon but it was highly decreased in winter and post-monsoon season. Dogan and Ertan (2017) observed the amino acid composition of goldband goatfish (*Upeneus moluccensis*) and concluded that the level of glutamic acid was considerably increased in winter but moderately decreased in pre-monsoon season while it was highly decreased in post-monsoon season. Glutamic acid acts as an important neurotransmitter and is involved in the synthesis of other neurotransmitter such as gamma-amino butyricacid (GABA) thus its plays a critical role in healthy brain development and function.

The value of aspartic acid was highly increased in monsoon, moderately decreased in pre-monsoon while it was considerably decreased in winter and post-monsoon season. Dogan and Ertan (2017) observed the amino acid composition of goldband goatfish (*Upeneus moluccensis*) and concluded that the level of aspartic acid was significantly increased in pre-monsoon, slightly decreased in winter but considerably decreased in monsoon and post-monsoon season. Aspartic acid plays a vital role in the synthesis of glutathione, precursor for essential amino acids and regulates the secretion of important hormones (Mohanty *et al.*, 2014). The level of cysteine in the liver of fish was considerably increased in post-monsoon, slightly decreased in monsoon while it was moderately decreased in pre-monsoon and winter season. Chrisolite *et. al*., (2016) experimented on seasonal variation in the proximate composition of emperor fish (*Lethrinus lentjan*) and concluded that the level of protein was considerably increased in winter, slightly decreased in pre-monsoon while it was highly decreased in monsoon and post-monsoon season. The body can convert cysteine into glucose for a source of energy. Cysteine also plays a role in the communication between immune cells system.

The level of tyrosine in the liver of fish is highly increased in monsoon, moderately decreased in pre-monsoon season while it was considerably decreased post-monsoon and winter season. Ozyurt and Polat (2006) studied a seasonal differentiation and amino acid composition of wild sea bass (*Dicentrarchus labrax*) and estimated the level of tyrosine was considerably increased in autumn, slightly decreased in summer and winter while it was moderately decreased in spring season. Tyrosine is a precursor for several biologically active substances including catecholamine, neurotransmitters, hormones and melanin skin pigments. The level of glycine in the liver of *Labeo rohita* was moderately increased in monsoon and slightly decreased in other seasons. Chakraborty *et. al*., (2014) worked on seasonal dynamics of amino acid of ribbon fish (*Trichiurus lepturus*) and reported that the level of glycine was significantly increased in monsoon, considerably decreased in pre-monsoon season but highly decreased in post-monsoon season in south west

coast of India and different alteration was seen in south east coast of India, the level of glycine was considerably increased in post-monsoon, moderately decreased in pre-monsoon but highly decreased in monsoon. Glycine plays an important role in metabolic regulation, enhancing antioxidant activity, promoting protein synthesis and wound healing.

In our study the value of alanine in the liver of fish was significantly increased in monsoon, slightly decreased in pre-monsoon but it was considerably decreased in winter and post-monsoon season. Effong *et .al*., (2008) worked on seasonal variation on the nutrient composition in selected fish species and observed that the value of alanine was slightly increased in pre- monsoon season and slightly decreased in monsoon season. The nonessential amino acid alanine is highly beneficial for supporting gluconeogensis and leucocyte metabolism (Kudsk, 2006). In the present study it was found that level of proline in the liver of fish was considerably increased in monsoon moderately decreased in pre-monsoon while it was highly decreased in winter and post-monsoon season. Nisa and Asadullah (2011) experimented on seasonal variation in chemical composition of the Indian mackerel (*Rastrelliger kanagurta*) and evaluated that the level of protein was significantly increased in monsoon, slightly decreased in post-monsoon and pre-monsoon season while it was highly decreased in winter season. Proline is a precursor to hydroxylysine so it is vital in the formation of collagen and other tissues such as tendons, ligaments and muscles of the heart. The level of serine in the liver of fish was highly increased in monsoon, moderately decreased in pre-monsoon while it was significantly decreased but remain unchanged in winter and post-monsoon season. Yildiz and Mensah (2017) studied on seasonal variation on fillet amino acid profile of sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) and compared the level of serine, it was moderately increased in summer season and slightly decreased in winter season in *Sparus aurata* but the level of serine was moderately increased in summer and slightly decreased in winter season in *Dicentrarchus labrax.* Serine is the precursor of glycine, cysteine, and tryptophan and plays many important roles in cell signalling.

The changes in amino acid contents in fish liver were affected by spawning period and feeding physiology of fish, and some part of protein was used by fish for spawning, resulting in an increase in the level of protein in fish eggs. Protein and amino acid contents vary from species to species due to certain factors such as the season of the year, effect of spawning and migration and food availability (Abdullahi, 2001).

The level of ω-3 fatty acid in the liver of *Labeo rohita* was significantly increased in monsoon, considerably decreased in pre-monsoon season while it was highly decreased in post-monsoon and winter season. Hong *et. al*., (2015) worked on seasonal variation of fatty acid profile in different tissue of bigheaded carp (*Aristichthys nobilis)* and standardised that the ω-3 fatty acid was significantly increased in monsoon, slightly decreased in post-monsoon while it was considerably decreased but remain unchanged in pre-monsoon and post-monsoon season. Salma and Missaouin (2013) studied the seasonal variation of fatty acids composition in muscles of European eel and found that the value of ω-3 PUFA was increased in winter, moderately decreased in summer and autumn but it was considerably decreased in spring season. Nutritional variation depends upon weather condition and indicate that decline in water content, fat content evidently increased due to heavy feeding during this period reported by Huss (1988; 1995). The plankton concentration in water is at the highest level during post-monsoon and winter, which could explain the increment in both fat and protein contents observed. After winter protein content of fishes decreased again to an almost stable level for the following period, which might be associated with egg development this usually spawns early monsoon.

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• Volume 8 • Number 1 • January-June 2018

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