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Millets –The Nutrition Hub for All

T. Kungumaselvan

Assistant Professor, Agricultural Extension,
Adhiyamaan College of Agriculture & Research, Krishnagiri-635 105.
E- mail: kungumaselvanagri@gmail.com

Introduction

"India is honored to be at the forefront of popularizing Millets. Millet consumption furthers nutrition, food security and welfare of farmers"

-Honorable PM Narendra Modi

Millets, being grown in more than 130 countries, have been considered an integral part of the diet of over half a billion people across Asia and Africa for centuries. In India, Millets were among the first crops to be domesticated. In addition to many health benefits, millets are also good for the environment with low water & input requirement. Recognizing the enormous potential of Millets to generate livelihoods, increase farmers' income and ensure food & nutritional security worldwide, the Government of India (GoI) has prioritized Millets. In April 2018, Millets were rebranded as "Nutri Cereals", followed by the year 2018 being declared as the National Year of Millets, aiming at more extensive promotion and demand generation.

History and Cultivation of Millets

There is evidence of the cultivation of millets in the Korean peninsula around 3500 B.C. In India, millets have been mentioned in Yajurveda Texts. Millet was extensively cultivated till around 50 years back. But due to the Western development model, India has neglected its traditional wisdom. Millets are cited as too primitive and coarse grains. It was looked at only as the food of rural people or ancestors. Besides that, the Green revolution had a negative impact on the production of millet. Before Green Revolution, the millets are 40 percent of total grain production. India produces 170 lakh tons of millet. The global average yield is 1,229 Kg per hectare, while the average yield of millets in India is 1,239 kg per ha.

Millets and its types

S. No.	Common Name	Colour
1.	Sorghum/Jowar	Brown, deep red
2.	Peral millet/Bajra	White, yellow
3.	Ragi/Finger millet	Red to purple
4.	Tenai/Foxtail millet	White, yellow, red, brown, black
5.	Pani Varagu/Proso millet	White, cream, yellow, orange, red, brown and black
6.	Varagu/Kodo millet	Pink-ish
7.	Kudhiraivali/Barnyard millet	White-creamish
8.	Samai/Little millet	Off-white, creamish
9.	Browntop millet	Greenish with brown colour at the top

Source: India Science, Technology& Innovation, 2023

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Sorghum


Pearl millet


Finger millet


Foxtail millet


Proso millet


Banyard millet

Millet cultivation in India

n India, Jowar and Bajra are grown in most states like Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Gujarat, Rajasthan, Uttar Pradesh, and Tamil Nadu, except North East states, Himachal Pradesh and Jammu and Kashmir. Both can be grown as Kharif (July -November) and Rabi (October – February) crops. Traditional varieties of these crops are available in India. They exhibit a wide range of variations concerning duration and quality. They can be grown as sole crops, intercrop, and mixed crops. The crop duration varies from 90 -120 days. The mixed cropping of Jowar-Arhar and Jowar with other pulses and even Bajra and other cereals could be done.The crop rotation of mung followed by Jowar improves soil fertility. Bajra can also be grown as a mixed crop.

Finger millet (Ragi) is an important cereal of Karnataka. It grows as summer and Rabi crops in Southern India but mainly as a Kharif crop in Northern India. It can grow in alkaline soil with a pH as high as 11. The duration of the Ragi crop is 135 days. It grows as the sole crop in Southern India and Orissa, as a mixed crop with Jowar, Bajra, Oilseed, and Pulses, and as an off-season crop in rice fallow.Foxtail (Italian) millet can grow under tropical and temperate conditions. It grows throughout the year in Southern India. The duration of the crop is 80-100 days. The Little millet and Barnyard millet are also produced under rainfed conditions. Both can withstand drought and waterlogging conditions. Proso, Kodo, and Browntop millets are highly drought resistant. Browntop has the shortest duration of 70-75 days among all millets.

Millets are also grown in irrigated conditions. One to two ploughing is enough for the cultivation of millets. The seed rate for sowing varies from millet to millet. 3 to 4 rain is sufficient to grow these crops.Thesowing is done through seed drill or dribbling. Nitrogenous fertilisers or phosphatic fertilisers are required in small quantities. There is a minimum or no requirement for pesticides. The panicles contain grains, and the stalk and leaves are utilised as fodder for animals.

Role of Millets in Sustainable Development Goal 2

Sustainable Development Goal 2 aims to achieve "zero hunger". It is one of the 17 Sustainable Development Goals established by the UN in 2015. The official wording is: "End hunger, achieve food

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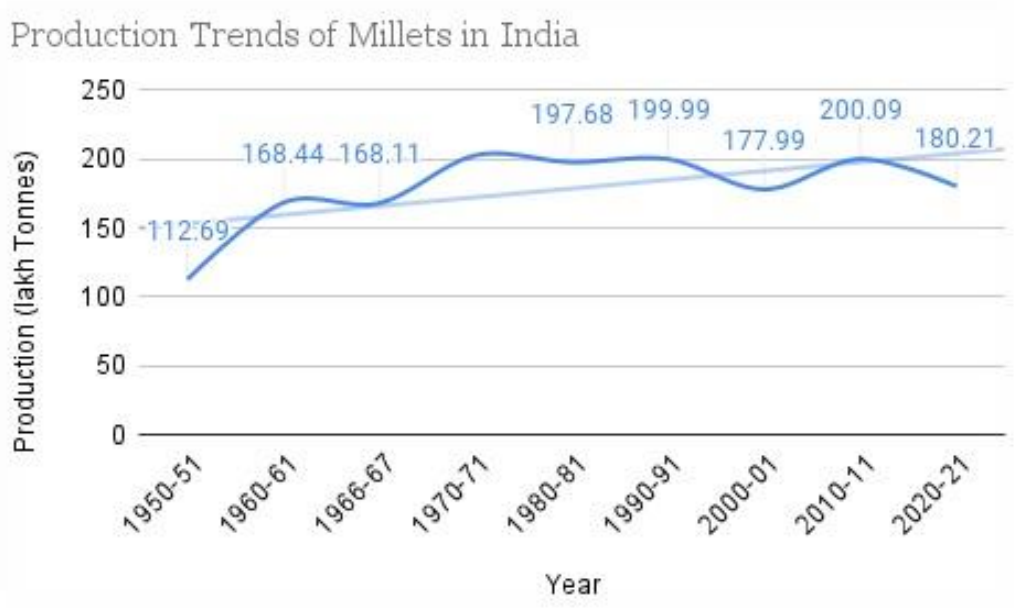
security and improved nutrition and promote sustainable agriculture. A profound change in the global food and agricultural system is needed to nourish today's 800 million people. It can be possible by focusing on millet production. Nearly 40 per cent of the global land surface is dry land. Millets are the most suitable crop for dry land agriculture.



Source: Millet Network India, 2023

International Year of Millets 2023: Initiatives taken and proposed activities:

The Indian government had suggested to the united nation for declaring the year 2023 as the International Year of Millets (IYOM). India got the support of 72 other countries, on 5th March 2021, United Nations General Assembly (UNGA) declared 2023 as the International Year of Millets.

The initiative of the Indian government is of celebrating IYOM 2023, it is done by making the population aware of the millet benefits and increasing the acceptability of the value added of millet across the country and world.

The international year of millet gives a thriving opportunity to

1. Increase the contribution of millet to food security.
2. Increase the global production of millets
3. Ensuring efficient processing, transport, storage, and consumption.
4. Sustainable production and quality of millet with the involvement of the stakeholder.

Millets and Health

Millets are rich in non-starchy polysaccharides, fibre, and low glycemic index, which controls blood sugar levels, and arethe ideal grain for diabetic patients. The soluble fibre and millet protein help to improve gut health and reduce cholesterol levels. Millets are gluten-free grains, a viable choice for people with celiac disease. Ragi is an excellent source of calcium and is suitable for bone health, blood vessels, muscular contraction, and nerve function. Kodo millet is rich in iron. It purifies the blood, reduces hypertension, and regulates the body's immune system. Foxtail millet keeps neurons (brain cells) healthy. Little millet is good for the thyroid. Because of the goodness of nutrients, these are termed

Nutri cereals. These should be part of the daily diet, and each millet should be consumed in a week on a rotational basis. Bajrais best to eat in winter and Jowar in summer.Barnyard millet is usually eaten during religious fasts and is suitable for liver health. Browntop millet has anti-cancerous properties. Kutki, Sama, and Kagni can be substituted for rice.

These are coarse grains, so prior soaking of 6 to 8 hours before cooking is required. Traditional millet recipes like millet roti and millet khichdi already exist on the regional level. Besides that, many innovative recipes like millet dosa, millet idli, pancakes, millet bread, waffles, crispy crumbs in the salad, and cookies are developing professionally in hotels, bakeries, and also at home. New ideas to improve its palatability and acceptability by all age groups will end the hidden hunger and can fulfill the goal of zero hunger. Millet farming can play a crucial role in sustainable agriculture and make farmers prosperous.

Conclusion

Millets are water saving, drought tolerant crops. Therefore, they must be viewed as climate change compliant crops. Like Ragi, other millet crops also have to be supplied to the people through Public Distribution System. This enhances the livelihood of the millet growers as well as improves the health of the rural people. The initiatives taken for the development an improvement of the millet farmers have to be highly monitorized to get good quality produce.

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Eyes in the Sky – Satellites: For Agriculture and Climate Change

Sridhara, M R*, Kavyashree C and L Shravika
Ph.D. Scholar, Department of Agronomy,
College of Agriculture, University of Agricultural Sciences,
Raichur - 584104 (Karnataka), India.
***Corresponding author*:** agrisridhar72@gmail.com

Abstract
Farm management is the most typical application of satellite data in agriculture. A crop's health and growth may be inferred from satellite pictures, which can also be used to estimate production. This can assist farmers in making intelligent choices regarding crop management practices, such as when to fertilize and in planning for harvest and sale. Over the past 50 years, satellites have been watching the Earth in real-time. With the use of this knowledge, scientists are better able to comprehend the processes that make up the Earth system, forecast future change and promote international cooperation.
Keywords: Agriculture, Climate change, Satellites, Sky

Introduction
It is becoming ever clearer that average temperatures and sea levels are rising and climate changes are occurring as a result of the global warming induced by the greenhouse gases such as carbon dioxide and methane emitted into the atmosphere through the activities of humans. There is rising concern that the risk of extreme weather phenomena such as droughts, heat waves and floods will increase if this situation remains unchanged. In order to prevent global warming and stabilize the climate system, it is necessary to reduce emissions of greenhouse gases. Monitoring of these GHGs also very much essential for the mitigation so, satellites from the skies are keeping keen observation on the environment and earth and updating frequently for taking precautionary measures.
Currently, over 4,000 satellites orbit the Earth, collecting a vast quantity of data that might help agriculture, including surface water, soil organic matter, and predictions of crop yields. Even photos of the ground may be captured by the best quality satellites at a distance of 0.41 meters (16 inches). The race for space has started anew as a flurry of private and government projects are once again reaching for humanity's last frontier.

Why Are Satellites Important?
A satellite is a moon, planet or machine that orbits a planet or star. For example, Earth is a satellite because it orbits the sun. Usually, the word "satellite" refers to a machine that is launched into space and moves around Earth or another body in space.
The earth observing satellites are helping in different sectors like commercial, governmental, critical military purpose, mixed purposes and several civilian operations. These use of satellites for various purpose making the operations easier, quicker and more precise in the execution. The satellite in the field of agriculture and climate change is more crucial because of this change climate scenario and helping prediction of future prospectus.

Satellites to study environment and climate
Global efforts to protect the environment involves continuous monitoring to bring the action plan. Experts say that greenhouse gases produced by human activity represent one of the biggest causes of global warming.

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1. IBUKI – GOSAT

The Greenhouse Gases Observing Satellite (GOSAT) "IBUKI" is the world's first spacecraft to measure the concentrations of **carbon dioxide and methane**, the two major greenhouse gases, from space. The spacecraft was launched successfully on January 23, 2009, and has been operating properly since then by Japan Aerospace Exploration Agency (JAXA).

"IBUKI" is able to measure the concentration of greenhouse gases such as CO_2 and CH_4 over almost the entire surface of the earth at equal intervals every 3 days from the orbit traveling around the earth in approx. 100 minutes. And it has been able to improve the estimation accuracy of the net flux of CO_2 by up to 40% until now through the use of these data.

Countries with the most satellites in Space

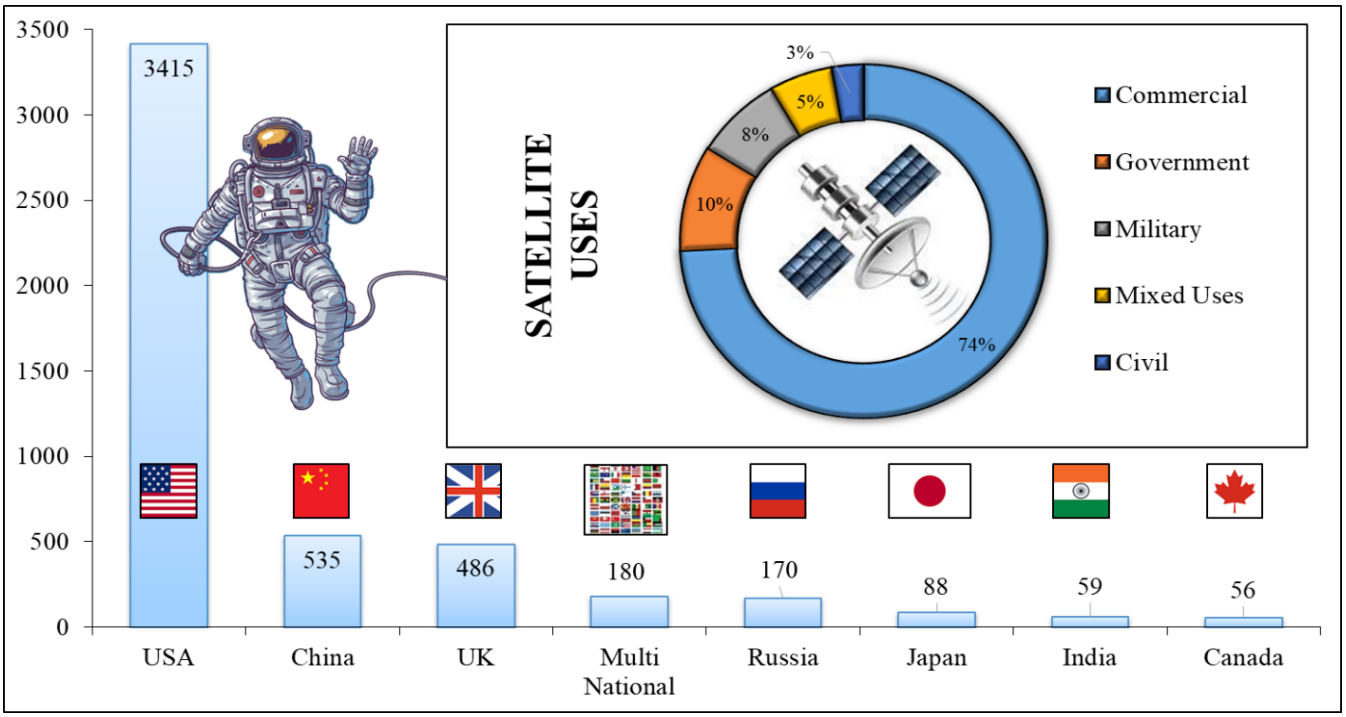

Fig. 1. Satellites currently orbiting earth by countries [as of May 2022]

Source: Union of Concerned Scientists Satellite Database (UCSSD, 2022)

Important space agencies in the world

ISRO	NASA	JAXA	ESA

According to JAXA, the IBUKI satellite is equipped with a greenhouse gas observation sensor (TANSO-FTS) and a cloud/aerosol sensor (TANSO-CAI) that supplements TANSO-FTS. The greenhouse gases observation sensor of IBUKI observes a wide range of wavelengths (near-infrared region–thermal infrared region) within the infrared band to enhance observation accuracy.

2. The IBUKI-2 "eye": An upgraded IBUKI

IBUKI contains on onboard Thermal and Near Infrared Sensor for Carbon Observation - Cloud and Aerosol Imager-2 (TANSO-CAI-2, hereafter CAI-2). Besides CAI-2, IBUKI-2's sensor suite contains the Thermal and Near Infrared Sensor for Carbon Observation – Fourier Transform Spectrometer (TANSO-FTS). Measurement by TANSO-FTS alone could yield data discrepancy due to interference by clouds and aerosols, suspended particulate matter in the atmosphere. CAI-2 is therefore designed to detect the existence of clouds and the distribution of aerosols and to provide the data for their correction. Compared to the original CAI onboard the IBUKI satellite launched back in 2009, CAI-2 has wider wavelengths and front and back viewing capabilities for more detailed monitoring of the concentrations of PM 2.5, black carbon and other types of aerosols.

GOSAT and GOSAT-2 are only satellites in the world that can observe both absorption of solar reflection from the earth's surface by the atmosphere and thermal radiation from the atmosphere from the space with its onboard spectrometers with the world highest spectral resolution.

	GOSAT	GOSAT-2
Main observation targets	Carbon dioxide, methane	Carbon dioxide, methane, carbon monoxide
Observation accuracy	4 ppm (carbon dioxide) and 34 ppb (methane) at a 1,000-km mesh over land	0.5 ppm (carbon dioxide) and 5 ppb (methane) at a 500-km mesh over land
Orbit altitude	666 km	613 km
Revisit time	3 days	6 days
Mass	1,750 kg	2,000 kg (maximum)

3. Global Change Observation Mission – Water "SHIZUKU" (GCOM-W) and Global Change Observation Mission - Climate "SHIKISAI" (GCOM-C)

The "Global Change Observation Mission" (GCOM) aims to construct, use and verify systems that enable continuous global-scale observations (for 10 to 15 years) of effective geophysical parameters for elucidating global climate change and water circulation mechanisms. The GCOM mission is a two series of satellites, GCOM-W for observing water circulation changes and GCOM-C for climate changes. The GCOM-W with a microwave radiometer onboard will observe **precipitation, vapor amounts, wind velocity** above the ocean, sea water temperature, water levels on land areas and snow depths.

The GCOM-C, carrying a SGLI (Second generation GLobal Imager), conducts surface and atmospheric measurements related to the carbon cycle and radiation budget, such as clouds, aerosols, ocean color, vegetation and snow and ice.

- **World's Largest Revolving Space Antenna AMSR2**

The Advanced Microwave Scanning Radiometer 2 (AMSR2,) which will be loaded onto the GCOM-W, is a sensor to observe radiometers, or microwaves emitted naturally from the ground, sea surface and atmosphere, using six different frequency bands ranging from 7 GHz to 89 GHz.

4. Global Precipitation Measurement (GPM)/ Dual-frequency Precipitation Radar (DPR)

Japan worked with NASA to measure tropical and subtropical rainfall through the Tropical Rainfall Measuring Mission (TRMM). The GPM program is designed to make more accurate and frequent observation of global rainfall by expanding the area of observation to include higher latitudes. By using precipitation maps with high accuracy, which are produced every hour about four hours after observations, as achieved in the GPM mission, it is possible to observe rainfall on the entire globe in near-real-time, and minimize flood-related damage, which in turn protects human life.

5. Advanced Land Observing Satellite-2 "DAICHI-2" (ALOS-2)

The state-of-the-art L-band Synthetic Aperture Radar-2 (PALSAR-2) aboard ALOS-2, which is an active microwave radar using the 1.2 GHz frequency range, will, in responding to society's needs, have enhanced performance compared to DAICHI/PALSAR. The PALSAR-2 is capable of observing day and night, and in all weather conditions.

Characteristics of "DAICHI-2" (ALOS-2)

1) Disaster monitoring of damage areas, both in considerable detail, and when these areas may be large
2) Continuous updating of data archives related to national land and infrastructure information
3) Effective monitoring of cultivated areas
4) Global monitoring of tropical rain forests to identify carbon sinks.

ALOS-2 has two objectives:

- To contribute to disaster management activities of the central and local governments in Japan and foreign countries by observing the disaster-stricken area widely in detail, regardless of the time (day and night) or weather, and establishing a system to quickly obtain, process, and share observation data; and,
- To promote data utilization in various fields with constant observation data to meet user needs such as monitoring social infrastructure (e.g. roads, railroad tracks, and bridges), understanding agricultural conditions, and observing forests.

6. Soil Moisture and Ocean Salinity (SMOS)

The Soil Moisture and Ocean Salinity (SMOS) mission, launched on 2 November 2009, is one of the European Space Agency's Earth Explorer missions, which form the science and research element of the Living Planet Programme.

It is the first mission to provide, from microwave L-band measurements, global observations of variability in soil moisture and sea surface salinity due to continuous exchange in Earth's water cycle between the oceans, the atmosphere and the land. These key geophysical parameters, soil moisture for hydrology studies and salinity for enhanced understanding of ocean circulation, are both vital for climate change models.

7. PROBA-V

PROBA-V, launched on 7 May 2013, is a miniaturized ESA satellite tasked with a full-scale mission to map land cover and vegetation growth across the entire planet every two days. The objective of the PROBA-V ('V' for Vegetation) mission is to support existing applications such as: land use, worldwide vegetation classification, crop monitoring, famine prediction, food security and disaster monitoring and biosphere studies.

8. Earth Clouds, Aerosols and Radiation Explorer (EarthCARE)

EarthCARE is an earth observation satellite that **Japan and Europe** have been jointly developing. Using its four sensors (Cloud Profiling Radar, Backscatter Lidar, Multi-Spectral Imager and Broadband Radiometer), clouds and aerosols (small particles like dust and dirt that exist in the earth's atmosphere) will be observed on a global scale to improve the accuracy of climate change predictions.

World's First On-board Cloud Profiling Radar (CPR) with Doppler Speed Sensor aboard a Satellite

In cooperation with the National Institute of Information and Communications Technology (NICT), JAXA is responsible for the development of the Cloud Profiling Radar (CPR), which will be the world's first W-band (94GHz) Doppler radar aboard a satellite.

The CPR transmits millimeter-waves toward the earth from the satellite's orbit and receives radio waves scattered by the cloud particles. Using the largest antenna ever made, the CPR can make observations with sensitivity ten times higher than current cloud radars aboard satellites by transmitting a large amount of electricity.

9. Orbiting Carbon Observatory – 2

NASA successfully launched its first spacecraft dedicated to studying atmospheric carbon dioxide on July 2, 2014. Orbiting Carbon Observatory-2 (OCO-2) is Earth remote sensing satellite to study atmospheric carbon dioxide from space.

10. Jason – 3

Jason-3 is the fourth mission in U.S. - European series of satellite missions that measure the height of the ocean surface (Sea level). Launched in 2016. It does this for the entire Earth every 10 days, studying how global sea level is changing over time.

11. **Satellites designed for benefit of farmers in India**

The satellite-enabled services in conjunction with ground data, to support farmers in India include weather forecasting, agro-advisory, agromet services, soil moisture and agricultural extension activities to support farming operations in the country by India Meteorology Department (IMD), Ministry of Earth Sciences. Also, Indian Space Research Organization (ISRO) collaborates with Ministry of Agriculture and Farmers Welfare on various applications using satellite data and geospatial technology in agriculture sector.

The satellites designed by ISRO, which are currently in operation, to support these services and applications, include Resourcesat-2, Resourcesat-2A, RISAT-1, Cartosat-1, Kalpana-1, INSAT-3D and INSAT-3DR.

Sl. No.	Satellite (Launch Vehicle)	Objectives
1.	Resourcesat-2 (PSLV-C16)	To provide multispectral images for inventory and management of natural resources, Crop production forecast, wasteland inventory, Land & Water Resources development, and Disaster Management Support.
2.	Resourcesat-2A (PSLV-C36)	
3.	Cartosat-1 (PSLV-C6)	To provide high resolution images for Cartographic mapping, Stereo data for Topographic Mapping & DEM, and host of DEM Applications – Contour, Drainage network, etc.
4.	RISAT-1 (PSLV-C19)	To provide all weather imaging capability useful for agriculture, particularly paddy and jute monitoring in kharif season and management of natural disasters.
5.	Kalpana-1 (PSLV-C4)	To provide meteorological data to enable weather forecasting services.
6.	INSAT-3D (Procured launch)	Designed for enhanced meteorological observations, including vertical profile of the atmosphere in terms of temperature and humidity for improved weather forecasting and disaster warning.
7.	INSAT-3DR (GSLV-F05)	

12. China is developing its own **TanSat** and France is working on the **MicroCarb** satellite to survey CO_2 emissions which could be helpful in future to agriculture and climate change analysis.

Conclusion

The space technology helps getting fast and unbiased information about the crop situation in the country. It provides digital data, which is amenable to various analysis. Because of its synoptic view, it provides images of the whole country in a very short duration. Hence, this data can be used for various programmes, which need information on crop type, crop area estimates, crop condition, crop damages, crop growth etc. The information about the atmosphere and whole earth which helps in analyzing the situations and prediction of the weather for now and for the future.

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Impact Of E-learning During Covid-19

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M Deepika[1] and T. Kungumaselvan[2]
[1]*Teaching Assistant, Agricultural Extension, Gandhigram Rural Institute- Deemed to be University, Dindigul, Tamil Nadu - 624 302.*
[2]*Assistant Professor, Adhiyamaan College of Agriculture and Research, Athimugam, Krishnagiri, Tamil Nadu- 635 105.*
Corresponding authors: dpsrish@gmail. com

Introduction

E-Learning, or electronic learning, is the delivery of learning and training through digital resources. Although e-Learning is based on formalized learning, it is provided through electronic devices such as computers, tablets and even cellular phones that are connected to the internet. This makes it easy for users to learn anytime, anywhere, with few, if any, restrictions.

Basically, eLearning is training, learning, or education delivered online through a computer or any other digital device.

The History of e-Learning

To better understand how eLearning benefits organizations today, it's helpful to look at its past. Elliott Maisie coined the term "eLearning" in 1999, marking the first time the phrase was used professionally. In the years since, e-Learning's reputation has gone from strength to strength.

- **Benefits of eLearning**
  - **Cost Effective**

This is one of the most significant benefits eLearning presents, and probably the most welcome! Traditional training can be expensive and often frustrating to maintain. eLearning removes the need for costly printed training materials and even on-site instructors.

- **Saves Time**

e-Learning allows us to easily add them to your LMS. This saves us a considerable amount of time on the organization of reprints, etc. Learners can also save time by accessing content where and when they need to, rather than relying on scheduled training.

Improves Performance and Productivity

e-Learning allows learners to quickly and more easily complete their training, resulting in improved performance and greater productivity. Learners appreciate that they can participate in training at their convenience. They're likely to feel more motivated to further their professional goals through eLearning, as it gives them the flexibility to learn at their own pace and from a location of their choosing.

- **Lower Environmental Impact**

More and more organizations are making a conscious effort to reduce their carbon footprint as part of their corporate responsibility strategy. eLearning is an effective method if we aim to have a lower environmental impact. It offers an alternative to paper-based learning and contributes to a more sustainable and environmentally-friendly workplace.

COVID 19- An unprecedented crisis

COVID 19 is a global pandemic caused by SARS COV-2, it caused the global countries to undergo an unprecedented crisis, due to its fast spread and mortality caused to the human kind.Global

countries had forced lock down to restrict movement of people to stop the fast spread and it had caused more impact to the people in multidimensional losses. According to the World bank forecast the spending of government is expected by reduction of 5.7 % from the planned previous estimates. Most Government institutions around the world had closed educational institution to control the spread of Covid-19. In the pandemic situation of Covid-19 learning was realised online and knowledge transferred virtually.

Online educator compensates – by creating a supportive environment for all the students to participate in online leaning

Online learning: encouraged during Covid -19 due to

- Maintain social distancing and also can acquire knowledge
- Offers highly effective learning environment
- Offers complementary interactive support
- Flexible scheduling
- Available in any location with an internet connect and own devices
- Deals with real-time student monitoring and reporting

Initiatives In India

- Digital initiatives of MHRD & UGC

  SWAYAM online course (Study Webs of Active Learning for Young and Aspiring Minds). It was launched in July 2017. It is free of cost and registration and course selection can be done on interest basis

  E PG PATHSHALA

  An MoE Project. It is of high quality, curriculum based, interactive e content across all disciplines of social science, arts & humanities, natural and mathematical sciences. It is an open source and no certificates will be issued

  SWAYAMPRABHA

  A group of 32 DTH channels in diverse disciplines to all teachers, students & citizens interested in life long learning. It is free to access and also through cable operators. Useful for school education and higher education.

  CEC UGC YOUTUBE CHANNEL

- The Consortium for Educational Communication popularly known as CEC. It is mainly to address the issues of accessing higher education through electronic media. It is enriched with educational programmes and e content.

UG/PG MOOCS

Massive Open Online Course It has free online courses and is merged from open educational resources. By attending quiz the certificates are provided

Conclusion

- e-learning became inevitable after this pandemic: throws light on how students and perceive online learning environment
- It was observed that students had a favourable perception towards online learning except for few constraints like network issues and lack of direct interaction
- Though physical classroom teaching has resumed after a while, the importance and relevance of online learning has not gone down.

- From the academic staff perspective, online learning has improved and diversified their technical knowledge, still the issue of non -response from students is one major problem as perceived by them
- Hence it is necessary that we need to improve the online learning environment and make it more comfortable for the students.
- Constraints should be addressed both at the local & policy level so that e-learning moves into a new dimension replacing the traditional classroom teaching

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Unlocking the Potential of Fish /Animal Nutrition: Ameliorate Growth Performance and Nutritional Security through Feed Fortification with Additives

Patekar Prakash[1*], Ravi Baraiya[2], Sanjaykumar Rathod [3], Samikshya[1], Abinaya R[4]
[1*]*Ph.D. Scholar Fish Nutrition, Biochemistry and Physiology Division, ICAR-Central Institute of Fisheries Education, Versova, Mumbai-400061, Maharashtra, India*
[2]*Department of Fish Processing Technology, KUFOS, Kerala.*
[3]*Division of AAHM, ICAR-CIFE, Mumbai.*
[4]*Department of Fisheries Resource Management, KUFOS, Kerala.*
**Corresponding author* – patekarprakash476@gmail.com

Abstract

Animal nutrition is a critical component of livestock production systems, as it directly influences animal health, welfare, and productivity. The use of feed additives in animal nutrition has gained much attention in recent years as a means of enhancing animal performance and addressing nutritional deficiencies. Fish feed fortification with additives involves the inclusion of essential nutrients, such as vitamins, minerals and amino acids, in animal feed to enhance the nutrient content and improve animal health and growth. Animal nutrition plays a crucial role in ensuring food security and human well-being. Probiotics and prebiotics are commonly used to improve gut health, while enzymes can enhance nutrient digestion and absorption. Organic acids are used to reduce microbial contamination and improve feed preservation, while antioxidants are used to protect against oxidative stress and enhance shelf-life. This article gives insight into the viability of feed fortification with additives to augment fish/animal nutrition and facilitate sustainable livestock production. The authors expound on the underlying mechanisms that confer efficacy to these additives and furnish fundamental information regarding their usage. Feed additives hold promise as a prospective remedy for enhancing animal nutrition, curtailing environmental repercussions and satisfying the mounting need for superior feed.

Keywords: *Animal nutrition, Feed additives, Enzymes, Sustainable livestock production.*

Introduction

Feed additives are small quantities of substances that are incorporated into feed ingredients or diets to enhance or maintain their quality. These additives can serve as preservatives, binders, feeding stimulants, or even feed attractants. Specific ingredients or combinations are added to the primary feed mix to meet particular requirements and are generally used in small amounts. In aquaculture, feed accounts for somewhere between 50–80% of the production costs. One of the essential components of aquaculture is proper nutrition. The right diet and affordable production costs are essential for successful aquaculture. The price and quality of the feed additives and components that are employed throughout the feed formulation process determine the nutritional value and cost of the feed, respectively. Ingredients for feed include both organic and inorganic parts. To enhance the feed quality, the fish feeding efficiency, their health and overall performance, feed additives were added during the feed preparation. Most feed additives, including antioxidants, immunostimulants, probiotics and antibiotics, are nonnutritive and are introduced to culture systems to enhance growth and water quality.

Feed manufacturers have started using functional feed additives to combat rising prices (Yousefi et al., 2019). There has been much research on the use of various additives in fish diets to reduce psychological stress. The additive type, in addition to the species component, is crucial in differentiating the stress response. In the literature, a variety of feed additives have been tested in various species, resulting in a range of physiological reactions that have not just focused on the stress system (Herrera et al., 2019). Feed additives improve growth performance, which can help the aquaculture industry become lucrative.

Furthermore, several kinds of research have shown that the better benefits of dietary inclusion of feed additives are connected with increased feed consumption, which likely enhances immunological response and increases weight gain. Feed additives were beneficial due to their special therapeutic characteristics and eco-friendly metabolism in the digestive system. It is primarily significant for aquaculture applications because of its involvement in immune response enhancement, binding site competition, antibacterial substance generation and nutritional growth performance.

Properties of feed additives

- Feed additives should not have any harmful effects.
- It should not react with feed ingredients.
- It should not alter the nutritional quality of the feed negatively.
- It should not reduce the feed's desirable qualities by affecting its taste, appearance, flavor and texture.
- It should be available in sufficient quantities at a reasonable cost.

Types of feed additives

There are two types of feed additives

- Nutritive feed additives- Vitamins, minerals and amino acids, etc
- Nonnutritive feed additives- Binders, preservatives, etc

Feed additives

- **Probiotics**
- **Prebiotics**
- **Binders**
- **Dietary amino acid**
- **Immunostimulant**
- **Antioxidant**
- **Probiotics**
- **Antibiotics**
- **Pigments**
- **Preservatives**
- **Chemoattractants and feeding stimulants**
- **Hormones**
- **Enzymes**
- **Vitamins and minerals**

Probiotics

Probiotics are living microorganisms administered into the gastrointestinal tract (GIT) with diet or water to promote good health by improving the internal microbiological balance (Amoah et al., 2019). Fuller (1992) revised the definition as "live microbial feed supplement which beneficially affects the host animal by improving its intestinal microbial balance. In aquaculture, however, *Vibrio* spp., *Bacillus* spp., lactic acid bacteria, yeast and microalgae are mainly utilized as probiotics for growth and survival enhancement and reduction of the pathogen. It is important, especially for early life stages, since their gut is sterile and adding probiotics helps build up beneficial bacteria faster. Probiotics have

been proposed as an eco-friendly way of preventing disease in aquaculture since 2008 (Wang et al., 2008).

Prebiotics

Prebiotics are non-digestible food ingredient that beneficially affects the host by selectively stimulating the growth and/or activity of one or a limited number of bacteria in the colon, thus improving host health. It is given as a feed for probiotics. A non-digestible dietary component known as a prebiotic positively influences the organism by selectively promoting the activity of one or a few specific bacteria in the gut. The use of prebiotics in rearing fish and shellfish has received less attention than other terrestrial species; despite the potential advantages to health and performance, the following factors have been looked upon in prebiotic research on fish and shellfish: growth, feed utilization, intestinal microbiota, cell loss, barrier properties to pathogenic bacteria and innate immune parameters like alternative complement activity, lysozyme activity, natural haemagglutination activity, respiratory burst, superoxide dismutase (SOD) activity and phagocytic activity (Ringø et al., 2010). The primary application of prebiotics, such as organic acids, is to sterilize feed that contains a variety of infectious and pathogenic organisms (Hinton et al., 1985).

Some of the prebiotics

Non-digestible carbohydrates, Some peptides proteins, Oligofructose, Transgalacto oligosaccharides (TOS), Lactulose, Isomalto oligosaccharides (IMO), etc.

Binders

Fish feed needs to be stable enough to endure typical handling and transportation without breaking. In addition, the fish feed has to be relatively water-stable. The starch found in the fundamental constituents of feed is gelatinized after cooking and serves as a binder in feed. Agar-agar, carboxymethylcellulose (CMC), bentonite, guar gum, lignin sulphate, plaster of paris, polyvinyl alcohol, sodium alginate and wheat gluten are among the substances used as binders used at a level of 2 to 8% to increase pellet stability (Hardy and Barrows, 2003). Heat-induced gelatinization of carbohydrates during diet preparation assists in the binding of the final feed. Any binder used in the production of fish feed pellets must be

i) It must be water stable for at least two hours.
ii) The binder must function as a source of carbohydrates in the feed and promote palatability.
iii) A binder must be inexpensive and easily available.

Binders are substances that are used in aquaculture feeds.

- ✓ To improve the efficiency of the feed manufacturing process by reducing the frictional forces of the feed mixture through the pellet dies, thereby increasing the output and horsepower efficiency of the feed mill.
- ✓ To increase pellet firmness and reduce the amount of fines produced during processing and handling.
- ✓ To improve water stability of feed.
- ✓ To minimize disintegration & loss of nutrients due to leaching.
- ✓ To improve the efficiency of the feed manufacturing process.

Classification of binders

Nutrient binders: Corn gluten, Cotton seed meal, Wheat gluten, Pre-gelatinized starch.

Non-Nutrient binders: Bentonite, Lignin sulfonate, Hemicellulose extract, Tapioca flour, Carboxymethylcellulose (CMC), Alginate, Agar.

Dietary amino acids

Providing amino acids (AA) for energy, development, protein synthesis and as substrates for essential metabolic processes, protein is the most expensive component of fish diets. AA engaged in cellular activities other than protein synthesis is referred to as functional AA. A lack or imbalance may

hamper body metabolism and equilibrium in functional AA (Andersen et al., 2016). Essential amino acids (EAA) are added as a supplement to the feed to get a balanced AA profile. So supplemental EAA is added, like lysine and methionine. Using all the EAA, it is possible to lower dietary crude protein levels by 2-3%, which is a substantial saving for the farmer. The concept of an ideal protein blend from feedstuffs and feed additives will greatly help with decreasing the amount of nitrogen excreted in animal waste.

Immunostimulants

Disease-related issues have emerged to limit aquaculture's expansion in recent years. Pathogenic organisms have been spread across nations as a result of rising disease instances and, in particular, the unrestricted movement of live sea organisms. Due to these viral and bacterial epizootics, the shrimp farming sector in India and other Southeast Asian nations has experienced enormous financial losses. Immunostimulants are pharmacological substances that, whether administered alone or in combination with an antigen, activate the nonspecific immune system or the specialized immunological mechanisms, making animals more resistant to microbial and parasite infestations. A wide range of bioactive active molecules, including those with antimicrobial, antioxidant, immunostimulant, growth-promoting and anti-inflammatory properties, has been used to improve the health of aquatic animals. A novel technique has been to use bioactive molecules in aquatic feed. This bioactive immunostimulant approach is dependable, reproducible and improves feed quality (Wang et al., 2017). It is an agent which stimulates the nonspecific immune mechanisms when given alone or through specific mechanisms. Hence, there are no environmental hazards and residual effects on fish which can be given orally or through the feed. Immunostimulants promote resistance to active infection by increasing general defensive mechanisms rather than stimulating particular immune responses. As a result, there is no memory component and the response will probably only last for a short time.

- ***Natural****:* Ginger, turmeric, tulsi, garlic.
- ***Artificial****:* Beta-glucan, levan, anthraquinone, sodium alginate.

Antioxidants

The energy value of a fat or oil is significantly reduced as a result of oxidative rancidity or lipid peroxidation. Unwanted oxidation in feeds can be prevented in a number of ways. It is important to take precautions to ensure that the components used in the feeds give appropriate margins of safety for the natural antioxidants lecithin and vitamins A and E. Feed should be made with as few unstable fats and oils or other pro-oxidants as possible when feasible. Commercial fish feeds have included antioxidants in the prior. Even though hundreds of chemicals have been studied, only a select number have demonstrated the qualities required to be used in finished feeds to avoid undesired feedstuff oxidations. In the absence of natural antioxidant protection, feedstuffs rich in PUFAs are highly prone to oxidative decomposition. It may cause a reduction in the nutritional value of the constituent lipids, protein and vitamins.

Rancidity makes feeds unpalatable and generates toxic chemicals.

Properties of antioxidants

- Inexpensive
- Non-toxic
- Effective at low concentrations (0.001–0.02%)
- Capable of surviving processing

Commonly used antioxidants are;

Synthetic antioxidant

i) Ethoxyquine @ 0.015%.

ii) Butylated Hydroxyanisole (BHA) @ 0.2%
iii) Butylated hydroxytoluene (BHT) @ 0.2%.

Natural antioxidant

i) Vitamin E
ii) Vitamin C

Antibiotics

It is a bacteriostatic or bactericidal substance added to feed to treat disease. Some feeds can be formulated with antibiotics to treat Vibriosis and other bacterial infections. In general, it has been observed that antibiotics promote the growth of young animals rather than that of adults. Feeds made with vegetable proteins respond favorably to antibiotics decreasing or stopping pathogen activity, Getting rid of microorganisms that create growth-inhibiting toxins, promoting the growth of beneficial microbes that provide nutrients, lower the number of microbes that compete with the host for nutrition. Boost the intestine's ability to absorb nutrients (Hardyand Barrows, 2003). Routine uses in the feed are not recommended. Three antibiotics approved in the U.S. are sulfadimethoxine, sulfamethazine and tetracycline (oxytetracycline, OTC).

- OTC is commercially available as "medicated" fish (shrimp) feed, 1,500 mg/kg
- Flavophospholipol- 10-40 ppm
- Virginiamycin-100ppm
- Zinc Bacitracin- 100ppm

Pigments

Fishes have a variety of colours that are defined by pigment compounds deposited in their bodies. These pigment chemicals include melanin, nitrogenous bases, luminous proteins, and xanthophylls and anthocyanins (Price et al., 2008). Carotenoids have been included in diets of salmonids, crustaceans and other farmed fish, mainly as pigments to provide a desirable coloration to these cultured organisms. Consumers subconsciously relate product color to nutritive value, healthiness, freshness and taste. Therefore, color is a decisive quality criterion that has to be maintained and optimized. The most significant types of pigments in fish and crustaceans are carotenoids. Astaxanthin and canthaxanthin give the skin and eggs colour. Because they are unable to convert xanthophylls to carotenoids, high-value culture species like salmon and red sea bream must consume these pigments. These species are given carotenoid supplements using natural materials like paprika, krill products, shrimp, and crab processing waste containing the necessary pigments. Carotenoids may not only contribute to improving quality by enhancing color but could also help to create a better image in the minds of consumers of aquaculture products. Astaxanthin is added at 50 ppm and fed to shrimp for six weeks to improve colouration.

Examples:- Capsanthin, Lycopene, Beta-8'-apo-carotenal, Lutein, Cryptoxanthin Violaxanthin, Canthaxanthin, Zeaxanthin, Patent Blue V, Curcumin.

Preservatives

Susceptibility of individual feed ingredients and formulated feeds to oxidative damage (oxidative rancidity) and microbial attack on storage. Substances are added to the feed to control the rate of deterioration, particularly from fungal attacks under favorable conditions of storage are susceptible to the growth of microorganisms like fungi, yeast and bacteria. Feedstuffs and rations with an elevated moisture content (> 15%) are prone to microbial attack and Relative humidity of 70-90% and a temperature of 25^0C in the tropics favour rapid growth of microbes. *Aspergillus, Fusarium and Penicillium spp*. are associated with spoilage.

Antimicrobial preservatives

Propionic acid or Ca, Na or K salt - 0.1-0.25%, Sorbic acid or Ca, Na or K salt, Benzoic acid or Na salt, Acetic acid, Formic acid, Citric acid, Ascorbic acid or Ca or Na salt, Gentian violet, Potassium and sodium bisulphite, Potassium and sodium metabisulphite, Propylene glycol.

Chemoattractants and feeding stimulants

Synthetic chemicals or natural ingredients containing chemicals like free amino acids elicit feeding responses or induce animal feeding behavior and help improve food intake. Attractants are a mix of chemicals containing nitrogenous compounds, including

- Free amino acids
- Low molecular weight peptides
- Nucleotides related compounds
- Organic bases

Two types of feeding stimulants used in aquaculture feed

Natural ingredients: Squid meal, mussel flesh, shrimp meal and waste, short-necked clam flesh, marine polychaete worms, blood worms, certain terrestrial oligochaete worms, marine fish oils, fish meal, fish soluble, fish protein hydrolysates, soybean protein hydrolysates.

Purified or synthetic chemical derivative: Mixtures of L-aminoacids; amino acid mixtures including glycine, alanine, betaine, proline and histidine.

Hormones

Growth hormone, thyroid hormone, gonadotropin, prolactin, insulin, and different steroids are among the hormones that cause fish to develop. Growth promoters include steroid hormones like androgen, estrogen, progestogens, and non-steroidal hormones like thyroxin (Naiel et al., 2020). Various natural and synthetic hormones have been used in aquaculture for

- inducement of spawning,
- sex reversal,
- production of mono-sex population,
- growth enhancement.

Hormones responsible for fish growth are 17-alpha methyl testosterone, growth hormone, thyroid hormone, gonadotropin, prolactin, insulin and various steroid. Hormonal control is used to produce monosex cultures of fish to reduce reproduction & increase growth. Ex: Androgenic steroids (ethyltestosterone) fed to tilapia fry more than 90% of males.

Enzymes

The inclusion of anti-nutritional factors like phytate (mMyo-inositol-1,2,3,4,5,6-hexakisphosphates, the primary phosphorus storage form, is one of the main issues with the use of plant proteins in fish feed. Fishes lack intestinal phytases necessary for effective phytate hydrolysis during digestion; hence, up to 80% of the total phytase content in plants may be present in the form of phytate and is essentially unavailable to them. Therefore, the majority of the phytate-phosphorus is eventually excreted into the water, which may lead to pollution through algae growth. Enzymes aid in the improvement of the fish's inability to properly and efficiently digest its nutrition. Additionally, complex carbohydrates, collagen in skin and bones, and other feed components are all broken down by enzymes (Strobel et al., 2012). Biological catalysts, proteolytic and amylolytic enzymes are used. It improves the nutritional availability of feedstuffs. Feed enzymes have to be robust to withstand variations in pH and temperature. They should have high-temperature stability to withstand palletization. It should have a long shelf life. Phytase breaks down indigestible phytic acid (phytate) in cereals(rice bran, wheat), oil seeds and releases digestible phosphorus.

- Use of specific enzymes like **xylanase, pectinase and cellulose.** Protein levels in feed could be reduced and hence the cost factor also.

Feed Stimulants

Chemoattractants, such as free amino acids, betaine, and other naturally occurring components, including chemicals, are synthetic or natural compounds. The main flavour attractants are often thought to be extractive chemicals found in the muscles of crustaceans and mollusks. These attractants are a mixture of substances made of nitrogenous molecules, such as free amino acids, peptides with low molecular weight, nucleotides, related compounds, and organic bases. The food supplied must be appealing (i.e., scent or taste) in order to evoke an appropriate feeding response, depending on whether the animal in concern is a visual feeder or a chemo-sensory feeder. For example, whereas captive marine fish rely on sight to find food, they also rely on chemo-receptors placed in the mouth or on appendages such as lips, barbels, and fins. Dietary feeding stimulants must be used to induce an adequate and quick eating response in these farmed species. Furthermore, by employing feeding stimulants and boosting feed palatability, the time the feed spends in the water may be decreased, reducing nutrient leaching.

Aside from the feed additives listed above, there are others, like amino acids, antibiotics, and immunostimulants. L-lysine and DL-methionine are the most common synthetic amino acids used in feed supplements. These are used to compensate for deficits in a compounded diet as well as chemoattractants. Antibiotic use is prohibited since medicated feed poses health risks to consumers owing to residual buildup in the fish flesh and may also open the route for the emergence of drug-resistant bacterium strains.

Essential oils

Using herbal food additives can boost the immune system, increase feed consumption, and enhance performance by avoiding infections (Ezzat Abd El-Hack & Alagawany, 2016). Essential oil can be used as an alternative source of natural products to improve animal nutrition and prevent detrimental effects on animal health.

The most prevalent form of phytogenic compounds in aquatic feeds are feed additives, including aromatic plant essential oils. Essential oils are secondary metabolites produced by aromatic plants and are concentrated hydrophobic liquid molecules with a strong odour. Most of the plant's active chemicals are found in them, along with a range of volatile molecules such as terpenoids, aromatic components generated from phenol, and aliphatic components (Chakraborty et al., 2014) derived products that are added to the feed to boost animal performance.

Essential oil of peppermint (Talpur,2014) and cinnamon (Ahmad et al.,2011) appear to be potential options for improving growth performance, fish well-being and reducing microbial challenges in the gut. According to Zheng et al. (2009), diets enriched with oregano essential oil and its phenolic components carvacrol and thymol were demonstrated to increase growth in channel catfish. Following eight weeks, fish fed the diet supplemented with the commercial product (0.05%) had considerably greater ($P < 0.05$) weight increase, protein efficiency ratio, and enhanced FCR than fish fed the other diets.

Organic acids

Environment-friendly organic acids and salts commonly used as substitutes, such as acetic acid, formic acid, fumaric acid, lactic acid, propionic acid and citric acid. In combination, they act as excellent growth promoters (Balasubramanian et al., 2016). Feed conversion efficiency has been tested in salmonids, tilapia, and other fish species (Ng & Koh, 2017). Citric acid and salts are aquaculture's most studied organic acids for growth and weight gain (Zhang et al., 2016). Additionally, the benefits of citric acid with coupled amino acid-chelated trace elements have been explored as giant yellow croaker given high plant protein to digest by 0.8%-1.6% of citric acid (Chen et al., 2018).

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