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STRATEGIES TO IMPROVE MOTHER-KID BONDING OF GOAT FOR KID SURVIVABILITY

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Abstract

Goats have a wide spectrum of maternal behavior and are frequently referred to as "hiders" when they are young. The survival and growth of newborn kids are dependent on the development of a maternal attachment at an early age. Mother often separate themselves from other group mates few hours before parturition, it facilitates to form a deep attachment with the newborn kids. Within half an hour or immediately after delivery, healthy kids stand up, seek out teats, and suckle. As a result, strong and exclusive maternal attachment is established between the doe and kids. Establishment of initial bonding between mother-kid occurs during sensitive period, since this stage is restricted to early learning of sensory cues which is transferred naturally with the mother. Olfactory signals are the most promising way for mother to recognize their own newborns. Several extrinsic factors affecting mother-kid bond includes nutrition, human interference and other external stimuli. However, some management strategies could initiate strong mother-kid relationship process and ensures the viability of newborn kids.

Keywords : Bonding, Mother-kid, Parturition and Sensory cues

Introduction

Domestic livestock species such as cattle, buffalo, goat, sheep and pig require good maternal care to ensure that offspring are survived. Mother is usually the main caretaker of the young at early neonatal life. The main difference between domestic ungulates (cattle, buffalo, goats and sheep) and altricial laboratory species (rat, house mouse and rabbit) is that their young are immobile and helpless at birth; in contrast, mothers in domestic ungulates give birth to precocious newborns capable of a high degree of independent activity from birth, which help in formation of mother-young bond. It is common for sheep and goats that not to build nests for their newborn young, unlike the other domestic ungulate species (e.g., sow). During the first postpartum hours of intense mother-kid care at the birth site, the doe leaves her kid for several hours, while the young hide and wait for her return for nursing. The physiological control of maternal care and mother-young bonding depends on the facilitation of learning by physiological changes occurring at parturition (Romeyer et al., 1994). Understanding of physiological and environment control on mother-kid bonding will help developing management strategies for improving this bond.

Importance of mother-kid bonding

In most domestic animals, parental care is mainly performed by mother. A strong mother-offspring bond is a key to the survival and growth of mammalian young one. Parental care in goats is largely performed by mother, who provides food (milk), warmth, shelter, and protection from predators and conspecifics. Goats rarely provide indiscriminate care to their offspring. Preferential

care of an own kid is often predicted on the dam's capacity to distinguish between its own and alien kids. The same applies to young kids' recognition of their mothers.

Figure 1.Maternal care of Black Bengal goat (A: Licking and sniffing of kids after birth; B: Post-partum successful suckling)

Figure 1 depicts the maternal care of kids after birth followed by the suckling of colostrum with successful mother-kid bond. When a proper mother-kid bond is developed the mother goat is always able to recognize her young quickly and reject any alien kids that attempt to suck from them (Poindron et al., 2003). This discrimination in goats is established within 2–4 hours after birth. Although selective nursing of kids relies on olfactory recognition, however, mothers can also identify their kids from a distance using visual and auditory cues (Mandal et al., 2022; Poindron et al., 2003; Nowak et al., 1997).The development ofa good mother-kid bond after birth will enable the kid's early colostrum intake. Besides supplying energy, colostrum contains immunoglobulins, especially in ungulates, which provide passive immunity (Das et al., 2022).Consequently, it will provide protection against numerous diseases of kids in the early phase of life. Therefore, early access to the udder is vital for the proper development of the mother-kid bond and survival of the neonate. This developed bond forms the base of future suckling and nursing to young that determines growth, development and future performance of kids.

How does the mother-kid bonding develop?

The most critical step during sensitive period is the successful development of mother-kid bond following parturition. The sensitive period is few hours prior and subsequent to kidding. Figure 2 depicts that prepartum success relies on the female's ability to choose an appropriate birth place that minimizes the risk of predators, disturbances, and misidentification of kids. This promotes postpartum success and initiates the development of the mother-kid bond. Most preparturient goats show a strong tendency to isolate themselves from the flocks (Yılmaz et al., 2012; Ramírez et al., 1995). This isolation-seeking behaviour of preparturient goats enables natural selection of birthplace and promotes the mother to express maternal behaviour. "Isolation seeking" refers to

the behavior of hiding and separating from disturbances (arising from different threats), so the female can give birth in a calm place, where she can then nurse and develops bond with her newborn young.

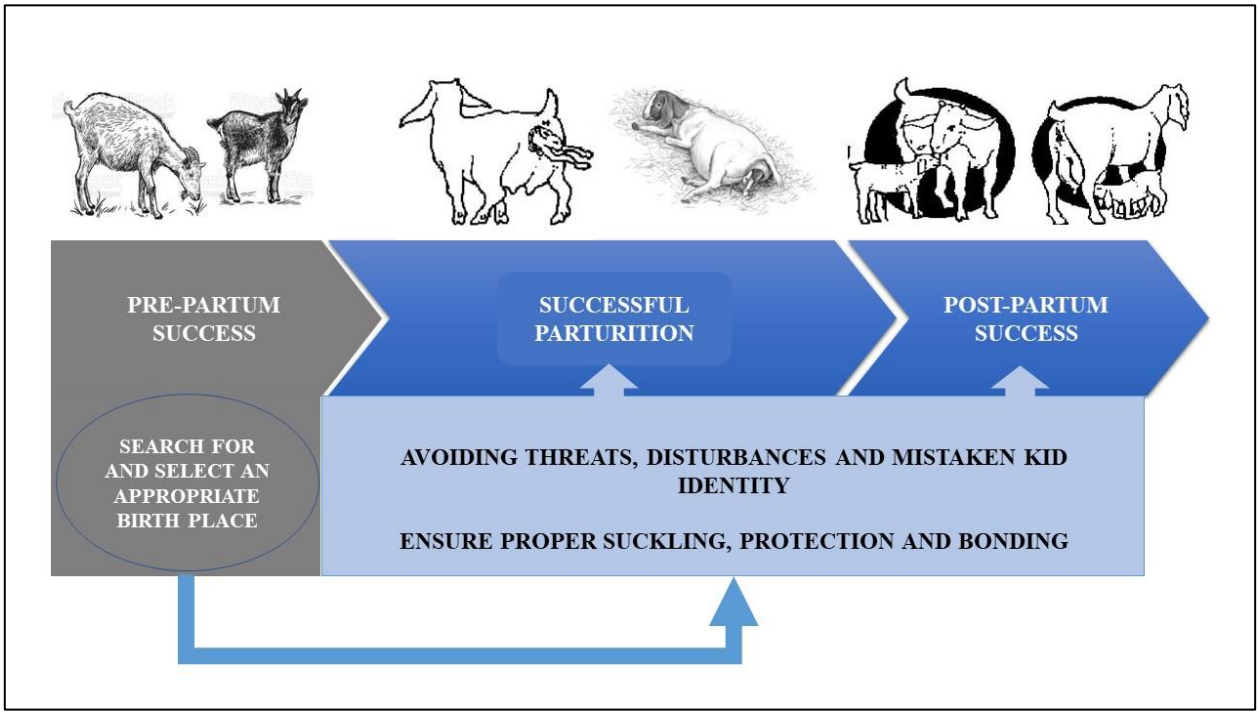

Figure 2. Development process of mother-kid bond in goats

The period when the bond is established is known as the "sensitive period," since it is a limited stage that is dependent on early acquisition of sensory cues (sight, touch, smell, and hearing) transmitted naturally with the mother or the environment during the newborn phase. The bond established at birth, which is dependent on a learning process is known as "imprinting". It allows the identification of the mother and important for the newborn survival. Immediately after delivery of the fetus, mother goats are highly attracted to the smell and taste of amniotic fluids, and lick the fluids that are coated over the kids' bodies. Licking of kids just after birth helps in drying up and stimulating the kids for suckling. This also transfers attraction and recognition to their newborn and develops selective bond with her kids. The most selective way for mothers to recognize their own newborns is through olfactory cues.

Factors affecting mother-kid bond development and survivability of kids'

The development of mother-kid bonding during the sensitive period is affected by the both maternal and infant factors (figure 3). The mortality of kids is always highest in the first few days after birth because of the difficulties in transitioning from a totally protected intrauterine life to an unpredictable extra-uterine life. The birth process itself is the first critical stage. Dystocia is one of the leading causes of perinatal kid mortality occurs due to trauma and fetal hypoxia. In such cases dam failed to exhibit maternal behavior due to stress and pain, thus hampering the development process of mother-kid bonding post-partum. After delivery, the newborn's survival will be primarily determined by the quality of interactions with the mother.

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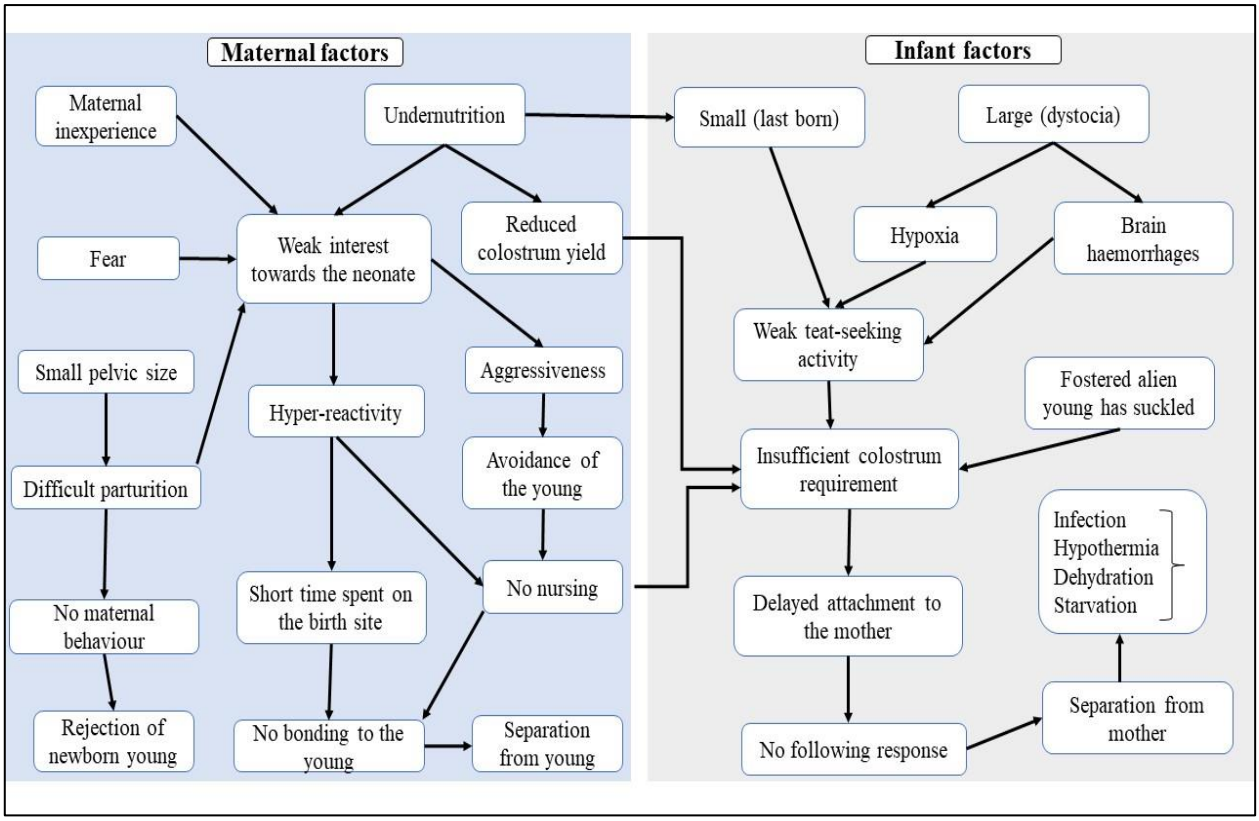

Figure 3.Factors responsible for failure of mother-kid bonding and kids' survivability

Mothers with inexperience have been identified as a possible cause of mortality in their kids. Neonatal rejection is most common in primiparous goats, and it may lead to starvation and mortality of kid. Does with little experience either show temporary delay in maternal care or display behavioural disturbances. It can delay neonate's access to the udder. These circumstances can reduce the chances of survival of kids, especially under adverse climate conditions.

Undernutrition during gestation leads to depressed maternal behavior of goats and high neonatal mortality of kids. However, poor bonding between mother and kid as well as perinatal kid loss may be strongly related to low birth weight of kid and mis-mothering as a result of undernutrition in the dam during pregnancy. A low level of maternal nutrition during pregnancy decreases the formation of mammary secretary tissue mass, which has an impact on the lactation period, resulting in less colostrum and milk for the offspring, which affects growth and the kids' survival.

Management strategies to improve mother-kid bonding for kid survival

Although the mother-kid bond development process is a completely natural process; however, there are few strategies which can help mother-kid bond development process and improve kid survivability.

a) Provide proper nutrition during pregnancy

Proper nutrition during pregnancy is important for mother-kid bond development and survival of kid at birth. Pregnant does ration must be supplemented with available green fodder @ 5-7 kg / head / day. The pregnant doe should be fed concentrate mixture @300-500g (16% DCP and 77% TDN) supplemented with adequate minerals and vitamins. The grain allowance should be lowered as kidding time approaches but good quality dry roughage should be offered free choice. It is

usually preferable to feed lightly on the day of parturition, but allow drinking plenty of clean and cool water. After parturition, gradually increase the concentrate mixture to sustain milk production. Good nutrition of the mothers during pregnancy reduces the chances of birth difficulty, poor mother-kid bonding and the birth of weak kids and thereby improves the chances of kid survivability.

b) Facilitate for natural selection of birth place

The parturient doe should be free for natural selection of birth place. Isolation of does from the rest of her conspecifics may be good to the establishment of early bond with their offspring. Natural selection of birth place promotes mothers to express good maternal behavior and habitat choices that increase the chances of their newborn's survival. This isolation aids in decreasing interference of newborns by other mothers or predators, both of which are detrimental for development of bond. Therefore, establishment of a mother-young relationship requires complete isolation from other goats. This behavior may promote mutual identification and quick access to the udder upon delivery. Therefore, isolation helps increasing the likelihood of young survival through proper development of the mother-young bond.

c) Housing management and provision of maternity pens

Pregnant does should be kept in separate kidding shed (maternity pens). The dimension of the shed shall be 1.5m(l)×1.2m(w)×3.0m(h), a manger for feed and a bucket for keeping water shall be provided. Floor of the shed should be non-slippery. Provide clean fresh straw for bedding. In cold climates some warming device, like a room heater or heat lamp or electric bulb shall be fixed, so that newborns are protected from cold stress during winter. Parturition in the isolated maternity pens keeps doe undisturbed from other adult female. It helps to create specific bond with kids, which will increase the survivability of newborns.

d) Early feeding of colostrum

Early feeding of colostrum is utmost important for survivability of kids. Early development of mother-kid bond facilitates early access to colostrum. The energy reserves of newborn kids are very limited. Colostrum, besides providing energy, contains immunoglobulins, which ensure passive immunity to the kids. Thus, early access to the udder is vital for survival of the neonate. Ingestion of colostrum at an early age triggers mechanisms that can also facilitate the establishment of mother-kid bond. Therefore, it is advised to feed colostrum within 30 minutes after the birth of kids.

e) Human assistance

Occasionally, human assistance is also required to initiate the mother-kid bond development process and increase the kid's survivability rate. During dystocia, the doe strained and failed to give birth and in such cases, human assistance become of paramount importance. This assistance could initiate early delivery of fetus and facilitate survivability. It also facilitates creation of early bonding between mother and newborn kid. It is evident that some primiparous does immediately after parturition, abandon newborn kids and resist licking due to nervousness and fear. In such cases, human interference is inevitable to bring the doe close to newborn kids and assist her in licking. This will help to dry up the amniotic fluid and further accept to suckle up the teats.

Conclusion

The success of bonding depends on the female's ability to identify an appropriate birth site that will ensure calm parturition and provide ideal conditions for postpartum expression of maternal

behaviors by eliminating predators, disturbances, and mistaken identity of offspring. The primary function of a mother-kid relationship is to provide nutrition, protection, and guidance to the offspring. Maternal care and suckling are essential to the development of the mother-kid bond and survivability of newborn kids. Hence, strong and exclusive bond between mother and kid will be an added advantage in terms of kid survivability, growth and future productivity.

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STATUS AND CONSERVATION OF *DUGONG dugon* IN INDIA: STRATEGIES FOR SPECIES RECOVERY

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Introduction

Dugong (*Dugong dugon*) also called as 'Sea Cow' is one of the four surviving species in the Order Sirenia and it is the only existing species of herbivorous mammal that lives exclusively in the sea. It is usually found in calm sheltered, nutrient-rich water, generally in bays, shallow island, and reef areas which are protected against strong winds and heavy seas and which coincide with extensive sea grass beds and such seagrass habitats are still available in Gulf of Mannar, Palk Bay, Gulf of Kutch, and Andaman and Nicobar islands in India. However, dugongs are not confined to only inshore waters and have been sighted near reefs up to 80 km offshore in waters up to 37 m deep.

Status of global distribution of Dugong and their habitats

Dugongs only occur in tropical and sub-tropical waters of the Indo-Pacific region. Their range is extensive, spanning 48 countries and territories from East Africa to Vanuatu. Approximately 85,000 of the world's dugongs are found in the inshore waters of northern Australia. The second largest dugong population occurs in the Arabian Gulf where the population was estimated in 1987 at 7,310 dugongs. Mauritius, the Maldives and parts of Cambodia and Laos have small and fragmented population. Dugongs are classified on the global Red List of IUCN as 'Vulnerable to extinction' and are included inAppendix I of the Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Status of Dugong in India

The dugong distribution in India was reported as abundant but limited to Andaman and Nicobar Islands, Gulf of Mannar, Palk Bay, Gulf of Kutch, and Lakshadweep Islands. The most favoured dugong habitats were the Gulf of Mannar in Tamil Nadu. Gulf of Mannar had a good population of dugong but due to illegal take of this species let the population under threat. Dugong population remained in western India was in the Gulf of Kutch. Due to intensive fishing and various developmental activities, the dugong population in the Gulf of Kutch was at the verge of extinction.

Threats to Dugongs and their habitats in India

Dugong distribution is mainly confined to seagrass beds, which occur in calm sheltered habitats, such as bays and lagoons. There is an increasing demand to use these coastal zones for residential, recreational, and agricultural purposes. These activities will make the coastal zone more susceptible to the pollution, which cause the destruction and degradation of the sea grass beds.Dugong has been reported to accumulate mercury and organochlorine compounds in the muscles.

- Incidental catch during fishing
- Poaching
- Pollution
- Seagrass habitat degradation
- Boat traffic
- Disease
- Indigenous use and hunting

Current status of regional conservation

The Dugongs are protected under the Schedule-I of the Wildlife (Protection) Act 1972, which provides the maximum protection to a species in the Indian territory and also prevents any kind of trade on this species.

- Globally vulnerable to extinction (IUCN,2015).
- Critically endangered in India.
- Listed in Appendix -1 of CITES which prohibits international trade.
- Listed in Schedule -1 of wildlife (protection)Act ,1972.

National Dugong task force is constituted by the MoeFCC, govt. of India to address Dugong conservation issues as per UNDP-CMS MoU. Task force include wildlife of Gujarat, Tamil Nadu and Andaman and Nicobar Islands. National dugong conservation plan has been drafted.

Conservation strategy and action plan

Goals and objectives of the Conservation strategy and action plan for dugongs and their habitats in India are as follows

Goal 1: Improve understanding

Objective 1. Improve our understanding of dugong through research and monitoring

Action	Priority	Time-scale	Expected outcome
1.1. Determine the distribution and abundance of dugong populations	High	Immediate	Information population estimates and distribution patterns
1.2. Conduct research and monitoring of dugongs	High	Continuous	Regular research and monitoring to assess and review conservation efforts
1.3. Identify causes of mortality and other possible threats to dugongs and their habitats.	High	Continuous	Information and data to improve conservation practices

Objective 2. Improve our understanding of dugong habitats through research and monitoring

Action	Priority	Time-scale	Expected outcome
2.1. Identify dugong habitats including foraging areas and migratory routes	High	Immediate	To identify important and critical areas for conservation
2.2. Conduct research and monitoring of dugong habitats	High	Continuous	Promote dugong conservation on the basis of findings of research and monitoring

Goal 2: Conserve Species

Objective 3. Reduce direct and indirect causes of dugong mortality			
Action	Priority	Time-scale	Expected outcome
3.1. Identify, assess, and evaluate threats to dugong populations and develop appropriate measures to address these threats	High	Continuous	Data will help develop the appropriate conservation measures for the different types and levels of threats.
3.2. Reduce illegal take of dugongs	High	Continuous	Control of illegal take of dugongs
3.3. Reduce incidental capture and mortality of dugongs	High	Continuous	Reduce mortality rates
3.4. Reduce dugong mortality due to other direct anthropogenic activities such as boat hits	High	Continuous	Reduce mortality rates
3.5. Reduce indirect anthropogenic threats, e.g., marine pollution	High	Continuous	Reduce mortality rates

Goal 3. Conserve habitat

Objective 4. Conserve and manage dugong habitats			
Action	Priority	Time-scale	Expected outcome
4.1. Identify and map dugong habitats such as seagrass beds and migratory routes	High	Immediate	Critical habitats identified and mapped
4.2. Identify direct and indirect pressures on dugong habitats	High	Immediate	Prioritize pressures on dugong habitats.
4.3. Develop and implement necessary measures to protect and/or conserve dugong habitats	High	Continuous	Dugong habitat is protected
4.4. Rehabilitate degraded dugong habitats	Medium	Continuous	Recovery of degraded dugong habitats

Goal 4. Promote awareness and education

Objective 5. Develop awareness for conservation of dugong and its habitat			
Action	Priority	Time-scale	Expected outcome
5.1. Develop and implement education and awareness programs	High	Continuous	Increase awareness of the different stakeholders
5.2. Encourage participation of local communities and private sector in conservation efforts	High	Continuous	Involvement of local communities and private sector in conservation activities
5.3. Work toward including marine biodiversity particularly endangered species such as dugongs in school curriculum	Medium	Continuous	Increase awareness on dugongs and their habitats

Goal 5. Develop legal framework

Objective 6. Develop legal protection of dugongs and their habitats			
Action	Priority	Time-scale	Expected outcome
6.1. Work toward incorporating dugong and habitat conservation measures into national legislation	High	Immediate	Dugong and its habitats that are outside the protected areas are need to be provided with appropriate legal protection
6.2. Review, and where necessary, strengthen national legal protection for dugongs and their habitats	High	Continuous	Laws and regulations protecting dugongs habitat are strengthened

Goal 6: Enhance national, regional, and international cooperation

Objective 7. Develop national, regional, and international cooperation on dugong research and conservation			
Action	Priority	Time-scale	Expected outcome
7.1. Develop and adopt mechanism for effective exchange of information	High	Continuous	Mechanism for cooperation and information sharing by range states are established
7.2. Improve coordination within and between countries for the conservation of dugongs and their habitats	High	Continuous	Coordination between various agencies established
7.3. Develop regional database of relevant information in relation to dugong conservation and management	Medium	Continuous	Shared database on dugongs and their habitats
7.4. Promote capacity building at all levels to strengthen conservation measures	High	Continuous	Capacity to effect dugong conservation enhanced

Objective 8. Promote implementation of the UNDP-CMS Dugong MoU			
Action	Priority	Time-scale	Expected outcome
8.1. Encourage all range states to participate in the dugong MoU and its activities	High	Continuous	The MoU includes all the range states
8.2. Seek resources to support the implementation of the MoU	Medium	Continuous	Sufficient resources available to implement the MoU
8.3. Create links and develop synergies with other relevant regional conservation conventions, MoU's, and agreements	Medium	Continuous	Support from other conventions for the conservation of dugongs and their habitats

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FISH FOOD ORGANISMS

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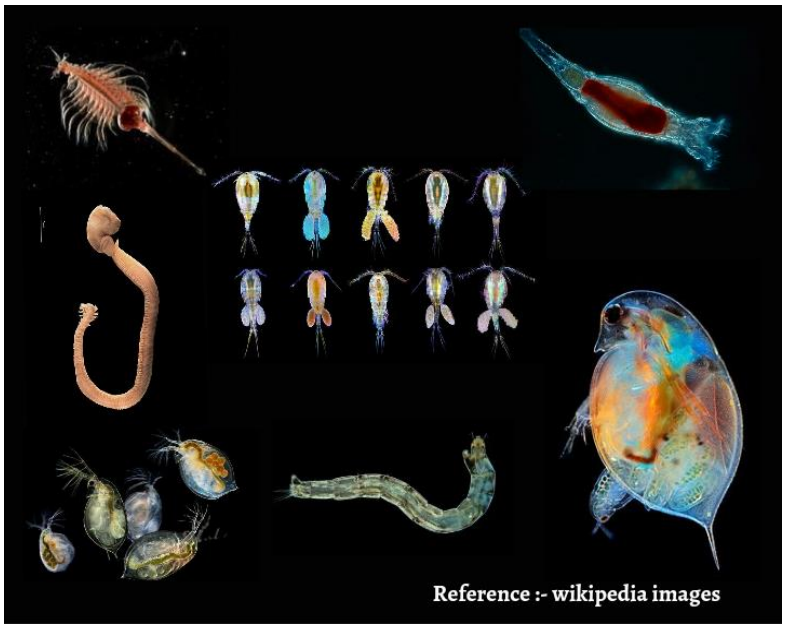
Fish food organisms are microscopic organisms naturally present in the aquatic environment as primary food for the larvae of fin fish and shell fish. Their size ranges from a micron to few millimetres. They are tiny forms which suits the mouth size of all kinds of fin fish and shell fish larvae. Eggs feed on yolk to become larvae. In the transitional phase from eggs to larvae they are delicate, they shift in size, gut changes along with digestive apparatus. Much of their protein digestion takes place in the hind gut epithelial cells. To overcome this fish food organisms play a vital role. The major expansion of finfish and shell fish aquaculture around the world is attributed to the development of standard mass production techniques of live feed. Live feeds are able to swim in water column and are thus constantly available to the larvae. Fish food organisms are mainly divided into protozoans, bacteria, phytoplankton, zooplanktons crustaceans and worms.



PHYTOPLANKTON

Micro-algae are indispensable in the commercial rearing of various species of marine animals as a food source for all growth stages of bivalve molluscs, larval stages of some crustacean species, and very early growth stages of some fish species. Algae are furthermore used to produce mass quantities of zooplankton (rotifers, copepods, and brine shrimp) which serve in turn as food for larval and early-juvenile stages of crustaceans and fish. Besides, for rearing marine fish larvae algae are used directly in the larval tanks referred as "green water technique", where they are believed to play a role in stabilizing the water quality, nutrition of the larvae, and microbial control.

The most frequently used species in commercial mariculture operations are the diatoms *Skeletonema costatum, Thalassiosira pseudonana, Chaetoceros gracilis, C. calcitrans*, the

flagellates *Isochrysis galbana, Tetraselmis suecica, Monochrysis lutheri the chlorococcalean Chlorella spp*. and eustigmatophycean, *Nannochloropsis spp*.

The nutritional value of any algal species for a particular organism depends on its cell size, digestibility, production of toxic compounds, and biochemical composition.

Although there are marked differences in the compositions of the micro-algal classes and species, protein is always the major organic constituent, followed usually by lipid and then by carbohydrate. Expressed as percentage of dry weight, the range for the level of protein, lipid, and carbohydrate are 12-35%, 7.2-23%, and 4.6-23%, respectively.

INFUSORIANS

The term "infusoria" comes from the practice of steeping substances (usually hay) in water by soaking at temperatures less than the boiling point. Only the largest of the protozoans (infusoria) are large enough to be seen by the naked eye. Most species require a microscope to view. The "green water" or cloudiness of aquarium water is sometimes an indication of an overabundance of infusoria which can be caused by overfeeding. The importance of infusoria to the pisciculturists is with their use as fry food. Their small size, ranging from 25 µm to 300 µm makes them an ideal live food for young fry which have just consumed their yolk sac. This includes ciliates and protozoan's. They obtain holozoic nutrition from bacteria, algae and detritus. They reproduce by binary fission or conjugation. Freshwater species includes Paramecium and Stylonichia and marine water species includes Euplotes (20-35 ppt).

Stylonichia is a genus of ciliate, included among the stichotrichs. It is very common in fresh water and soil, found on filamentous algae, surface films, and among particles of sediment.

Fabrea salina is heterotrichous ciliate, Fabrea salina had been reported from diverse environments such as salt marshes and hypersaline lakes.

ROTIFERS

Rotifers are microorgansims (100 to 2500 microns) that are readily found in aquatic and semi-aquatic habitats. Some are marine inhabitants, however most species are freshwater organisms. Currently there are over 1000 described species. They account for more than 90% of the zooplankton production in some freshwater systems and as such are a vital link in the food chain for most aquatic life. Rotifers are known to have a very high reproductive rate, reaching population densities of 1000 or more individuals per litre of water. The availability of large quantities of this live food source has contributed to the successful hatchery production of more than 60 marine finfish species and 18 species of crustaceans.

Rotifer's small size and slow swimming velocity make them a suitable prey for fish larvae that have just resorbed their yolk sac but cannot yet ingest the larger Artemia nauplii. Even at high densities, the rotifer reproduce rapidly and can thus contribute to the build up of large quantities of live food in a very short period of time. Last, but not least, the filter-feeding nature of the rotifers facilitates the inclusion into their body tissues of specific nutrients essential for the larval predators.

The life span of rotifers has been estimated to be between 3.4 to 4.4 days at 25o C. Generally, the larvae become adult after 0.5 to 1.5 days and females thereafter start to lay eggs approximately every four hours.

ARTEMIA

Nauplii of the brine shrimp Artemia constitute the most widely used food item among the live diets used in the larviculture of fish and shellfish. Artemia is only found at salinities where its predators cannot survive (> 70 g.l-1). As a result of extreme physiological stress and water toxicity Artemia dies off at salinities close to NaCl saturation, i.e. 250 g.l-1 and higher.

The direct use of Artemia cysts, in its decapsulated form, is much more limited in larviculture of fish and shrimp, compared to the use of Artemia nauplii. Nevertheless, dried decapsulated Artemia cysts have proven to be an appropriate feed for larval rearing of various species like the freshwater catfish (*Clarias gariepinus*) and carp (*Cyprinus carpio*), marine shrimp and milkfish larvae. Artemia is generally used for feeding the late larval and post larval stages of penaeids. Freshly-hatched nauplii are usually offered at the start of the first mysis stage, and sometimes even earlier at the zoea-mysis molt with some authors even recommending the introduction of Artemia during the second zoea stage.

Artemia nauplii is the most successful diet employed for the larval rearing of freshwater prawn larvae. In contrast to penaeid shrimp, Macrobrachium can initially be fed with freshly-hatched Artemia nauplii, at densities higher than 0.1 nauplii.ml-1 to ensure proper ingestion.

The larvae of many species of marine fish, such as gilthead seabream, grouper, and turbot, can only be offered an Artemia diet after an initial period on a smaller prey, such as the rotifer, *Brachionus plicatilis*.

In aquarium fish species live and frozen adult Artemia both are used as food. Cysts are also purchased by these users and hatched for feeding as nauplii.

COPEPODS

Copepods are common zooplankton both in freshwater and in brackish water. Their advantages being wide range of body size within and between species. They are natural feeds for larvae and juveniles of many finfish and crustaceans. The early stage nauplii and copepodites can be extremely useful as initial prey for species that have very small mouth gape at first feeding.

They are the largest class of crustaceans forming an important link between phytoplankton and higher trophic levels in most aquatic ecosystems. Most adult copepods have a length between 1 and 5 mm.

copepods may have a higher nutritional value than Artemia, as the nutritional profile of copepods appear to match better the nutritional requirements of marine fish larvae. Furthermore, they can be administered under different forms, either as nauplii or copepodites at start feeling and as on grown copepods until weaning. Moreover, their typical zigzag movement, followed by a short gliding phase, is an important visual stimulus for many fish which prefer them over rotifers. Another advantage of the use of copepods, especially benthos-type species like Tisbe, is that the non-predated copepods keep the walls of the fish larval rearing tanks clean by grazing on the algae and debris.

The nutritional quality of copepods is generally accepted to be very good for marine fish larvae, and believed to be of a higher quality than the commonly used live food Artemia. In general copepods have a high protein content (44-52%) and a good amino acid profile, with the exception of methionine and histidine.

CLADOCERANS

Daphnia (freshwater fleas), and Moina is most commonly known genus of Cladocerans. Cladocerans are free-swimming organisms, and most orientate themselves with dorsal side up. The head is typically separated from the body by a deep indentation, but also may not be separated.

Daphnia is a frequently used food source in the freshwater larviculture (i.e. for different carp species) and in the ornamental fish industry (i.e. guppies, sword tails, black mollies and platys etc.)

Daphnia belongs to the suborder Cladocera, which are small crustaceans that are almost exclusively living in freshwater. The carapace encloses the whole trunk, except the head and the apical spine (when present). Moina also belongs to the Cladocera and many of the biological and cultural characteristics that have been discussed for Daphnia can be applied to Moina.

The chemical composition of their food source determine the nutritional value of Daphnia. However, since Daphnia is a freshwater species, it is not a suitable prey organism for marine organisms, because of its low content of essential fatty acids, and in particular(n-3) HUFA. Furthermore, Daphnia contains a broad spectrum of digestive enzymes such, as proteinases, peptidases, amylases, lipases and even cellulase, that can serve as exo-enzymes in the gut of the fish larvae.

Daphnia is very sensitive to contaminants, including leaching components from holding facilities. When plastic or other polymer containers are used, a certain leaching period will be necessary to eliminate toxic compounds.

Primary habitat of moina is temporary ponds or ditches but also found in ponds and reservoirs. Reproductive maturity is about four to five days at 26°C. females (1.0-1.5 mm) are larger than Males (0.6-0.9 mm). Male have long graspers which are used for holding the female during copulation. Sexually mature females carry only two eggs enclosed in an ephippium which is part of the dorsal exoskeleton.

Moina is of a smaller size than Daphnia and also have high protein content and comparable economic value. Moina is successfully used in the larviculture of rainbow trout, salmon, striped bass and also used in form of frozen feed by tropical fish hobbyist.

TROCHOPHORA LARVAE

Trochophora larvae used as a starter feed for some marine fish species (i.e. siganids, groupers, snappers) very small zoo-plankton, because the commonly used rotifers are too big. Trochophora larvae belong to Pacific oyster Crassostrea gigas are 50 µm in size and free-swimming (slow circular swimming pattern) ciliated organisms which have a high nutritional value for marine fish larvae. For example, trochophora larvae may contain up to 15% (of total fatty acid) of both EPA and DHA.

MICROWORMS

CHIRONOMID LARVAE

Due to the presence of hemoglobin in their bodies, this worm get unique name "blood worm". The largest members among them belong to Chironomus genus. The larvae sustain on the organic material contained in the mud and are found in all kinds of still water where there is a deposit of mud and organic debris. Within 16-20 Days, larvae attain a size that suitable for feeding purposes. Its growth and development can be influenced by numerous environmental factors including

temperature and photoperiod, food availability and food quality and quantity. This larvae are excellent source of protein lipid, vitamins and minerals.

TUBIFEX

It is a hermaphrodite worm, as it has both male (testes) and female (ovaries) organs in the same species. reproductive organs of tubifexattached to the ventral side of the body wall in the celomic cavity. In mature specimens, the reproductive organs are clearly found on the ventral side of the body.

EARTHWORMS

From 500 species found in world, about 13 species are found in India. *Edulis engeniae, Eisenia fetida, Peryonyx excuvatus* are included in cultivable species of earthworm.

BAIT FISH

They are small fishes caught for use as bait to attract large predatory fish, particularly game fishes. Small fish produced specifically for anglers to attract desirable food or game fishes are referred to as baitfish. Baitfish is the common term given to a multitude of small, schooling fish as they are an important food source for other fish. Species used are typically those that are common and breed rapidly, making them easy to catch and in regular supply. This large and diverse group of fishes is an integral part of the complex, interconnected marine food web. Live bait fishes are used for chumming and attracting the tuna shoals. for operation of the pole and line fishery, Live baits are essential. reefs and lagoons are place where bait fishes usually caught. They kept in live condition in special region of the boats for use at the time of capture.

Spratelloides delicatulus, S. japonicus, Apogon sangiensis, A. savayensis, Chromis tematensis, anchovies, halfbeaks and scad are Examples of marine bait fish. Any fish of the minnow or carp family (Cyprinidae), sucker family (Catostomidae), top minnows or killifish family (Cyprinodontidae), shad family (Clupeidae), sculpin of the order Osteichthyes or sunfish family (Centrarchidae) are freshwater bait fishes.

Conclusion

Over the past two decades intensive larviculture of several fish and shellfish species has expanded into a multi-million dollar industry. Although much progress has been made in identifying the dietary requirements of the larvae of various aquaculture species, the mass A good selection of micro algal species is available to support the aquaculture industry. However for some particular applications for industry sectors, hatchery efficiency can be improved by improve nutritional quality of new species. The use of microalgae either as a full or partial enrichment should be considered for improving the nutritional quality of zooplankton. Culture of their early larval stages still requires the use of the live feeds. The availability of on-grown live food would not only offer farmers and exporters a better alternative option for feeding to their fish, but more importantly, the possibility of enhancing the fish performance and quality through bioencapsulation.

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AGRONOMIC BIOFORTIFICATION: A QUICK SOLUTION TO ALLEVIATE MALNUTRITION

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Nutritious diet is vital for proper growth and development in humans. It helps preventing diseases, besides maintaining the body metabolism for physical- and mental- well being. Food provides energy, protein, essential fats, vitamins, antioxidants and minerals to meet our daily metabolic requirement. Most of them cannot be synthesized in human body, therefore are to be supplemented through diet. Further, anti-nutritional factors present in edible parts of the food exert adverse effects on human health. Consumption of unbalanced foods affects billions of people worldwide, and leads to poor health and socio-economic conditions.

After the green revolution, there is a substantial increase in the productivity of food crops. But the nutritional aspect of the crops could not keep pace with the growing demand of the population. This has caused an increase in malnutrition problems due to the lack of a balanced diet. It has been reported that about 2 billion people are affected by malnutrition. Among them, almost 850 million people experience the ill effects of malnutrition.

Fortification is a feasible, cost-effective, and sustainable practice for delivering the content of essential micronutrients, vitamins, and minerals including trace elements in the food, that improve the nutritional quality of the food and help to reduce the risk of public health problems. Biofortification is the process of improving the nutritional quality of food crops using agronomic methods, traditional plant breeding, or modern biotechnology. Biofortified crops are those which have been nutritionally enhanced using agronomic practices, conventional plant breeding or modern biotechnology.

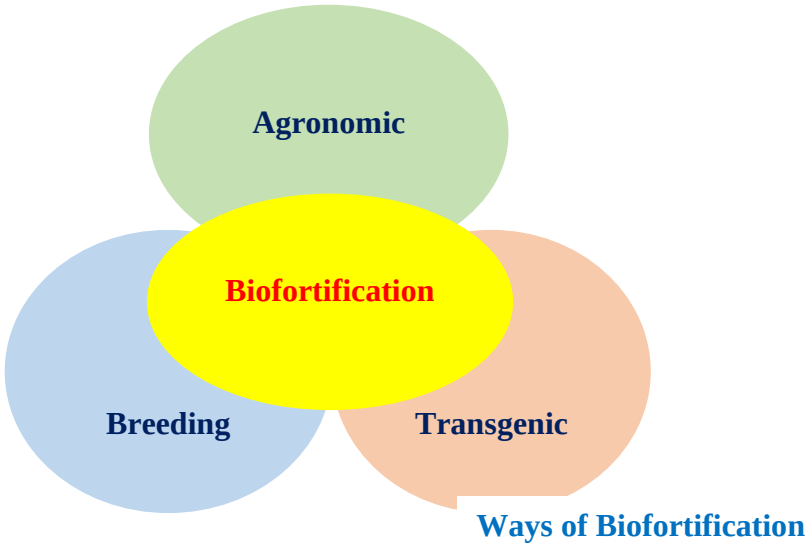
Need for Biofortification

Micro-nutrients are vitamins impact is critical and its deficiencies create serious ill-health like chronic diseases and stunting, weakening of immune system and reproductive systems and reducing physical and mental abilities. WHO estimates that, in 2017, over 6.3 million children under 15 years old and 5.4 million of them under 5, died as a result of malnutrition, particularly micronutrients. Malnutrition is estimated to affect more than half of the world's population, making it one of humanity's most critical global concerns.

Conventionally industrial fortification and pharmaceutical supplementation are major steps for alleviating malnutrition issues. But these things are low reachability to poor sometimes they reluctant to intakes of this tablet. So, the efficiencies of these strategies are low. Food-based approaches to improve nutrition face challenges in providing rigorous evidence that they can deliver nutrition improvements in a cost-effective and timely manner. So as an innovative step Biofortification introduced, it is an act of breeding nutrients into food crops, is a relatively low-cost, long-term way of increasing micronutrient delivery.

Biofortification approach not only will lower the number of severely malnourished people who require treatment by complementary interventions, but also will help them maintain improved

nutritional status. Moreover, biofortification provides a feasible means of reaching malnourished rural populations who may have limited access to commercially marketed fortified foods and supplements. The biofortification strategy seeks to put the micronutrient-dense trait in those varieties that already have preferred agronomic and consumption traits, such as high yield. Marketed surpluses of these crops may make their way into retail outlets, reaching consumers in first rural and then urban areas, in contrast to complementary interventions, such as fortification and supplementation, that begin in urban areas. Biofortified staple foods cannot deliver as high a level of minerals and vitamins per day as supplements or industrially fortified foods, but they can help by increasing the daily adequacy of micronutrient intakes among individuals throughout the life cycle.



Ways of Biofortification

Agronomic Biofortification

Agronomic biofortification is the process of increasing micronutrient content in food crops through agronomic approaches like integrated nutrient management (INM) based on soil test values, microbial application, foliar spray of nutrients, can substantially increase the level of micronutrients, vitamins, folic acid in food.

The main disadvantages of biofortification by traditional plant breeding or genetic engineering require not only a long gestation period and adequate funds, but also that the products are not accepted by consumers. Whereas agronomic biofortification is the easiest, fastest and most widely accepted way of reaching the poorest of the rural poor and making food rich in micronutrients, vitamins, folic acids.

Advantages of Agronomic Biofortification

- It is practiced on crop cultivars already being cultivated by the farmers and have good consumer acceptability of the produce.
- Enhanced micronutrient concentration in grain and other parts of the crop can be achieved in the same year.
- Very less amount of micronutrient is needed when the foliar application is followed.
- No investment is needed for new seed.
- Agronomic biofortification always creates a win–win approach.

Agronomic practices to increase nutrient concentration in edible part of plant

1) Maintaining soil health by physical, chemical, and biological properties

Soil health is one of the important factors regulating plant health by providing optimum conditions like proper root growth, increasing availability of nutrients, moisture-holding capacity and biological activity, optimum aeration for plants which helps to increase nutrients concentration in edible parts of plant.

2) Proper cultivation practices

a) Tillage : Tillage at optimum moisture conditions i.e., 50–75% moisture holding capacity is crucial for tillage operation as more or less moisture can create hardpan in subsoil which restricts root growth and hence reduce nutrient uptake and yield. Some improved tillage practices like a ridge and furrow planting, Furrow irrigated raised bed planting (FIRB) also help to increase the nutrient uptake by the crops.

b) Water management : As most of the nutrient uptake is done by mass flow and diffusion so soil moisture is the main factor that affects nutrient concentration in crop products. Optimum moisture helps in better root growth, increases the solubility of nutrients, and makes it available to the plants. Both excess and deficit water reduce nutrient concentration from the root zone by leaching or restricting mobilization.

3) Integrated nutrient management and Balanced nutrition

Nutrient application is the most important step for the agronomic biofortification. Integrated use of compost, manures, organic and inorganic fertilizer, microorganisms is the best way for a sustainable way of biofortification.

a) Application of organic matter : Soil organic matter improves soil health, it also has the capacity to supply all other nutrients to plants. The addition of organic matter shows a considerable increase in microbial biomass carbon, microbial community diversity. These biological properties of soils may help to maintain nutrient cycling and soil quality. The foods grown in organic conditions have greater nutrient content including minerals and vitamins.

b) Application of synthetic fertilizers : Application of macronutrients like N, P, and K is recommended based on soil test values and nitrogen should be applied in split doses. These nutrients promote root and shoot growth and increase uptake of all nutrients by the plants. Judicious use of macronutrients is most important to help in the proper uptake of other nutrients.

c) Micronutrient application and availability : Micronutrients simply follow a straight pathway to reach into the human body from the soil through the crop and food. The success of agronomic biofortification in alleviating micronutrient deficits in humans is determined by nutritional bioavailability at various stages.

d) Application of microorganisms : The most active site for the soil microorganisms in the rhizosphere where the nutrients are sequestrated, mobilized, and made available to plants. Bio-fortification of the crops can be done by using bio-fertilizer or microbial inoculants which mobilize or solubilize the essential nutrients and possess a positive impact on plants' health.

4) Other practices

a) Crop rotation : The beneficial effects of crop rotation include improved soil chemical and physical fertility, reduced weed infestation and diseases. The addition of pulse crops in the

cropping system is the best option after cereals for improving eating quality, not only because of their importance for humans and animals but also due to their soil ameliorative values and their ability to thrive under harsh and fragile environments.

b) Intercropping : Intercropping between soil exhaustive crop and the regenerative crop can create a complementary relationship and helps to reduce weed and disease infestation, protect the soil from nutrient mining, maintain soil physical, biological health and helps to increase nutrient density in them.

c) Proper pest management : Insects, weeds, diseases have a great impact on the quality as well as quantity of the product. They restrict the growth of the crops, sometimes can kill the plants. They also create a bitter taste in plants by producing some toxins. So proper management of them is of utmost importance. Integrated pest management is the best option to control their infestation as well as to maintain the quality of the product.

d***) Proper drying and storage :*** During post-harvest season grains that are not properly dried can sometimes develop mold and also some toxic substances like aflatoxins, ochratoxins, so proper drying is necessary. The grains like rice and wheat are exposed to contaminants, pests and diseases and prone to nutrient losses. So proper storage is important after harvest.

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DIFFERENT HERBS AND THEIR APPLICATION IN THE FIELD OF AQUACULTURE

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Abstract

The major part of the food production industry is aquaculture. It contributes almost half of the world's intake of fish food. Aquaculture will rise annually by 4.50% in 2020, 4.83% in 2021 and 5.15% in 2022. Aquaculture plays an important role in maintaining a healthy human diet. These organisms include a variety of nutrients, including proteins, lipids, and a variety of minerals. In order to mass produce while maintaining the stability of aquaculture, mediating variables are needed to improve the fishes' habitat, immunity, and growth rate. In this way, adding such herbs to animal diets to improve aquaculture seems advantageous because herbs are a natural and risk-free method. The addition of herbs and herbal items to fish feed helps to treat a variety of illnesses, foster growth, lessen stress, promote gonadal maturity, boost immunity and guard against infections in cultured fish. The use of herbs and herbal products in fish diets is less expensive and has fewer negative effects on both the fish and the consumers. The current article emphasizes the relevance of including herbs and herbal products in fish feed to improve fish production.

Keywords : Immunity, Growth, Plant extract

Introduction

Plants are an important aspect of our chemo-diverse planet. Many plants are sought after for a wide range of applications, including food, medicines, and cosmetics. In aquaculture, Due to the presence of various bioactive substances such as alkaloids, terpenoids, tannins, saponins, glycosides, flavonoids, phenolics, steroids, and essential oils, herbs and herbal extracts have been reported to have various properties such as growth promotion, appetite stimulation, anti-stress, immune system enhancement, broodstock maturation, aphrodisiac, and antipathogenic **(**Wu *et al.,* 2011). Furthermore, herbs and herbal extracts are less expensive, more environmentally friendly, and less likely to induce drug resistance due to the enormous diversity of plant extract molecules (Logambal *et al.*, 2000: Blumenthal 2000: Olusola *et ai.,*2013).

The following are some of the specialties of herb in aquaculture:

1. Herbs and herbal products such as garlic, onion, marjoram, caraway, basil, anise, fennel, licorice, black seed, and fenugreek have been shown to boost growth, feed conversion, protein digestibility, and energy retention in aquatic animals (Shakya 2017).
2. *Allium sativum*-enriched diets have been shown to considerably increase survival (Aly & Mohamed 2010), weight gain (WG), specific growth rate (SGR), feed efficiency ratio (FER),

and feed conversion ratio (FCR) in Nile tilapia (Shalaby *et al.,* 2006: Aly *et al.,* 2008a: Aly & Mohamed, 2010).

3. After 8 weeks of feeding, Mahdavi *et al.,* (2013) discovered that Aloe vera extract (0.1, 0.5, and 2.5%) was effective as a growth promoter and appetite stimulator for common carp, with a significant increase in weight gain and specific growth rate (SGR).
4. Hot pepper spices (e.g., capsaicin and piperine) and cinnamon (which contains cinnamaldehyde) are known to increase salivation (Chesson 1987).
5. Several studies have found that administering herbal plants or extracts to many fish species improves immunological parameters such as phagocytic activity, respiratory burst activity, nitrogen oxide, myeloperoxidase content, complement activity, lysozyme activity, total protein (globulin and albumin), and antiprotease activity (Dugenci *et al.,* 2003: Wu *et al.,* 2010: Yuan *et al.,* 2007: Wu *et al.,* 2013: Talpur and Ikhwanuddin 2012: 2013: 2014).
6. Mehrim *et al.,* (2015) discovered that Hydroyeast Aquaculture probiotic can improve physiological responses (haematological and serum biochemical parameters) as well as reproductive performances (sex hormones, testes and sperm quality parameters, absolute and relative fecundity, and ovarian measurements) in adult *O. niloticus* males and females at doses of 15 g and 10 g/kg diet.
7. In sharp snout sea bream, oral treatment of *O. minutiflorum* essential oil reduced the incidence of infection caused by *Myxobolus* sp (Karagouni *et al.,* 2005).
8. *P. granatum* extracts given intraperitoneally reduced the mortality of olive flounder infected with the lymphocystis disease virus (LDV) (Harikrishnan *et al.,* 2010e).

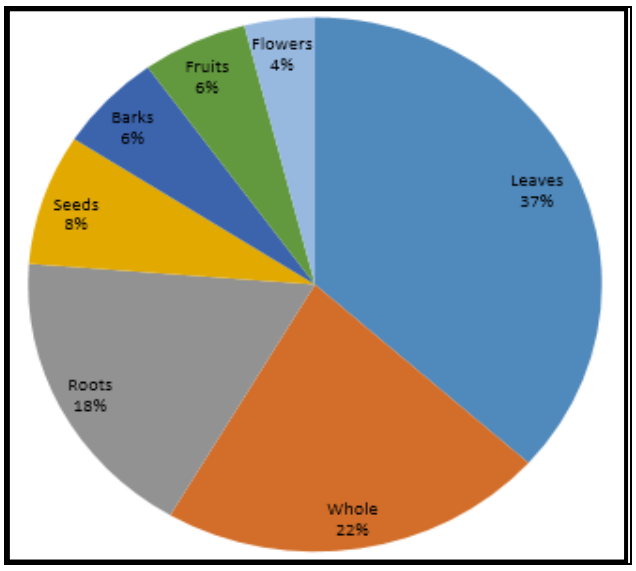

Fig. 1: Plants parts used in aquaculture. Source: Reverter *et al.*,(2017).

Table 1: Source of medicinal plants. Source: (A. R. Hodar *et al.,* (2019).

Medicinal plant	Plant part	Active compounds	Beneficial effect in fish diseases	Reference
Clematis chinensis	Roots	Saponins	Antiparasitic	Huang *et al.,* (2013)
Toona sinensis	Leaves	Triterpenes and Phenols	Antibacterial	Wu *et al.,* (2010)

Medicinal plant	Plant part	Active compounds	Beneficial effect in fish diseases	Reference
Punica granatum	Leaves	Polyphenols	Antiviral	Harikrishnan *et al.,* (2010c)
Camellia sinensis	Leaves and buds	Catechins	Antiparasitic	Suzuki *et al.,* (2006)
Citrus medica	Fruit	Limonene, geranial, and neral	Antiparasitic	Hu *et al.,* (2014)
Dioscorea collettii	Rhizome	Saponins	Antiparasitic	Hu *et al.,* (2014)
Carica papaya	Seed	Tannins, papain, nicotine,	Antiparasitic	Ekanem *et al.,* (2004) cyanogenic glycosides and quercetin

Application of herbs in Aquaculture sector:

The flavour imparted by herbs and herbal products added to fish diet modified eating patterns, increased feed consumption, and promoted digestion by boosting saliva, various digestive enzymes, bile, pancreatic enzyme activity, and mucus secretion in fish, which may be advantageous for aqua farmers**.**

Effect of Ashwagandha *(Withania somnifera)*:

Withania somnifera (Ashwagandha) is a member of the Solanaceae family. Winter cherry (*Withania somnifera*) possesses calming, rejuvenative, and aphrodisiac properties (Nazir and Chauhan, 2018). According to recent research, it is effective as a growth booster in aquaculture. Kumar (2000) demonstrated the effect of the herb Ashwagandha (Dunal) on the growth of an Indian major carp, *Cirrhinus mrigal*, and achieved promising results.

Palas *(Butea monosperma)*

Butea monosperma is a member of the Fabaceae family and is often known as Flame of the Forest. It is mostly effective as an antihelminthic, appetiser, aphrodisiac, laxative etc. (Prasad *et al.*, 2006). Malpani *et al.,* (2011) concluded that water extract of *Butea monosperma* gum performs as an antifungal agent under experimental settings. It also has a strong ability to prevent and repair the histological damage seen in gonads, suggesting that it could be employed to promote healthy reproductive activity in this fish model.

Giloy *(Tinospora cordifolia)*

It is a member of the Menispermaceae family. According to Siriphongsa that et al., (2018), *Tinospora cordifolia* crude extract (TCE) supplementation at 0.10% in broiler feed was sufficient to increase production performance, meat quality, and the amount of cecal *Escherichia coli* (E. coli) and Lactic acid bacteria.

Effect of Jaiphal *(Myristica fragrans)*

The aromatic evergreen tree belongs to the Myristicaceae family. According to Zhelyazkov (2018), common carp (*Cyprinus carpio L*.) grown in a recirculating system fed 1% nutmeg extract had a higher survival rate, better growth performance, feed conversion ratio, and economic conversion ratio than the non-supplemented group.

Velvet Bean *(Mucuna pruriens)*

Mucuna pruriens is a member of the Fabaceae family. In infertile obese mutant rat models, an ethanolic extract of *M. pruriens* seeds has been shown to significantly raise testosterone, LH, FSH, and prolactin hormone levels, levator ani muscle weight, sperm count, and motility (Kumar *et al.,* 2011).

Effect of Hing (*Ferula assafoetida*)

Ferula belong to family Apiaceae, according to Mahendra and Bisht (2012). The Asafoetida powder has the capacity to keep fish bodies healthy by influencing the body's non-specific immunity and ability to scavenge free oxygen radicals, hence increasing fish development performance (Huang *et al.,* 2006: Ye *et al.,* 2011; Wang *et al.,* 2012).

Garlic (*Allium sativum)*

It is a member of the Amaryllidaceae family. Yones et al., (2019) discovered that feeding 2% garlic powder to Nile tilapia (*Oreochromis niloticus*) broodstock improved growth performance, nutrition utilisation, immunological activity, productivity indices (Relative fecundity, Absolute fecundity, and Hatchability rate), and larval rearing rate.

Aloe vera (*Aloe barbadensis*)

It is a member of the Liliaceae family. According to the findings of Gabriel *et al.,* (2015a), Aloe vera extracts can be recommended as a tilapia feed additive to improve fish lipid profile status and enhance antioxidant and hepatoprotective activities, particularly during illness outbreaks.

Tea (*Camellia sinensis)*

It contains secondary metabolites such as catechin, caffeine, theanine, and saponin etc. Abdel-Tawwab *et al.,* (2010) discovered that include green tea in the diet of Nile tilapia resulted in lower fish mortality.

Conclusion

Aquaculture could benefit from the use of herbal extracts as crucial nutritional supplements. Each herb has a unique composition and impacts living organisms in distinct ways. Many studies are being conducted to investigate the efficacy of herbal supplements in fish feed in managing fish diseases and producing healthy fish. In conclusion, herbal feed additives increase growth, reduce stress, improve immunity, and prevent numerous illnesses in fish, all of which contribute to the production of healthy fish for human consumption.

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WILT DISEASE OF LENTIL

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Introduction

Lentil wilt is believed to be the most important constraint in lentil production worldwide and it may cause 5-10% yield losses but sometimes severe damage may result complete crop failure under the most favourable conditions for disease development (Fatima *et al.,* 2015). Wilt disease of lentil (*Lens culinaris Medikus subsp. Culinaris)* was reported in Hungary for the first time, and later on from many countries including India, USA, USSR, Syria and Turkey (Meena *et al.,* 2017). In India, Wilt disease of lentil was first reported from undivided Bengal in 1934 (Garkoti *et al.,* 2013). Thereafter, Dey (1948) reported the disease at other parts of India namely Kanpur and Banda and he described the causal organism as *Fusarium sp*. Lentil wilt disease may be caused by various pathogenic fungi like *Fusarium sp., Macrophomina phaseolina, Sclerotium rolfsii* and *Rhizoctonia bataticola (*Khare *et al.,* 1975, Wilson and Brandsberg, 1965, Mathur and Deshpande 1968). Chattopadhyay and Sen Gupta (1967) suggested the names of *Fusarium orthoceras* var. *ciceri*, *Fusarium orthoceras* var. *lentis* should be renamed as *Fusarium oxysporum* var. *ciceri* and var. *lentis* respectively.

Symptoms

The wilt disease affects the lentil crop in patches at both seedling and adult stages. Seedling wilt symptoms is characterized by sudden drooping, followed by drying of leaves and seedling death. The roots appear healthy, with reduced proliferation and nodulation and usually no internal discoloration of the vascular system. Adult wilt symptoms appear from flowering to late pod-filling stage and are characterized by sudden drooping of top leaflets of the affected plant, leaflet closure without premature shedding, dull green foliage followed by wilting of the whole plant or individual branches. Seeds from plants affected in mid-pod-fill to late pod-fill are often shrivelled (Bayya *et al.,* 1998) Many scientists have depicted the symptoms of the wilt disease in relation to the occurrence in different countries of the world. Narishmhan (1929), Erwin (1958) and Chauhan (1962), reported in that the wilt affected seedlings do not show symptoms of any external rotting however, downward discoloration of xylem vessels is found if the seedling is pulled up and split. Destruction of root structures and tissues in addition to infection proceeding from exterior to interior is noticed in the wilt disease (Carrera *et al.,* 1941). Dey, 1948 reported that hyphae were found to penetrate the vascular tissue of the root and stem resulting in death of the plant prematurely. Leaves become smaller and darker than the healthy ones and brownish red lesion are found in the root of young plants (Shulindin, 1950). Vasudeva and Srinivasan (1952), in their studies on the lentil reported wilt disease caused by *Fusarium orthoceras* var. *lentis* var. *nova* and noticed curling of the older leaves extending upwards crown and death of the plants. Coloured patches were also found in the leaves of wilted plants caused by *Sclerotium rolfsii* in the lentil fields at Varanasi (Pavgi and Upadhyay, 1967). *Sclerotium rolfsii* caused yellowing and drooping of the twigs resulting to the death due to collar rot (Verma, 1967 and Mathur and Deshpande, 1968). General yellowing of the leaves and discoloration of vascular elements are the main symptoms of

wilt disease (Mossahebi, 1968). Wilt caused by *Fusarium oxysporum* usually produces symptoms such as wilting, chlorosis, necrosis, browning of the vascular system, stunting and damping–off (Agrois, 1988). Disease symptoms on each plant were assessed two times per week till the flowering stage of the plant. The observations on seedling/plant mortality are converted to percent wilt for use on a scale of 1 to 5 where: 1(I) = 0% infection, 2 (R) = 1 to 15% plants wilted, 3 (MS) = 15 to 25%plants wilted, 4 (S) = 25 to 50%, 5 (HS) =50 % or more plants wilted. (Stoilova *et al.,* 2006)

Fig: Wilt of lentil.

Epidemiology

The causal pathogen is soil borne, which can survive in the soil and plant debris in the absence of its host for a period of 3-4 years. They are fond of acidic sandy soil and warm weather. It can survive in the soil for up to 10 years. The disease occurs either in the early stage of crop growth (seedling wilt) or during reproductive growth (adult plant wilt). Yield losses caused by the wilt disease depend on the stage at which the plant wilts; it can be 100% when wilt occurs at pre pod stage, about 67 % when it occurs at the pre harvest stage. Sometimes when the disease occurs under the most favourable environment conditions for disease development, it may cause severe damage and result in complete crop failure. The main epidemiological factors in increasing fungal growth rates and symptom expression are temperature and soil moisture (Falahati *et al.,* 2010). Moderately high soil temperature of 20-25°C is favourable for fungal growth whereas sunlight increases transpiration and noticed as the key factor to determine the symptom expression (Stoilova *et al.,* 2006). The optimal soil and air temperature for the pathogen is about 28°C according to Eagling, 2009.

Disease management

The development of resistant cultivars is the most sustainable and effective solution to this problem (Bayaa *et al.,* 1995). Some of wilt resistant varieties available in India are Pant L-4, Pant L-6, Pant L-8 and Noori. According to Garkoti and his co- workers in the year 2013, Integrated management strategies include lesser use of chemicals for controlling the pathogen population and encouragement of beneficial biological agents to suppress pathogen inoculums density and pathogenicity, modification of different cultural practices, using several resistant varieties and using various fungicides and use of biological control agents and organic amendments have promising outcomes in controlling the wilt of lentil. Soil amendment with organic matter enhances antagonism with other soil microflora, cultural practices such as ploughing of the field during summer, following crop rotation with non-host crops like cereals which are not affected by wilt pathogen. Carbendazim, Carboxin, Thiram, Benomyl @ 0.30% and Brassicol 0.2% are effective against wilt of lentil caused by *Fusarium oxysporum* f.sp. *lentis* and rot of lentil caused by

Rhizoctonia solani under field conditions. Many fungal and bacterial species like Pseudomonas, Trichoderma and Streptomyces having antagonistic effect on Fusarium wilt of lentil are extensively used as bio-control agent against soil and seed-borne wilt disease of lentil (Tiwari *et al*.,2017).

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