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MODELLING AND FORECASTING OF POSITIVELY SKEWED RESPONSE DATA : A REVIEW ON GAMMA REGRESSION MODELS

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ABSTRACT

The premise behind the class of gamma regression models is that the dependent variable has a gamma distribution and that the mean of the dependent variable is related to a collection of regressors through a linear predictor with unknown coefficients and a link function. The identity, the inverse, or the logarithm function can all serve as this connection. The logarithm function of the model additionally includes a shape parameter, which may be fixed or dependent on a group of regressors through a link function. In this article, we give a brief introduction to the idea of regression using the gamma distribution and present a quick review of the relevant literature.

Keywords: Gamma regression, gamma distribution, mean, linear predictor, link function, shape.

INTRODUCTION

When analysing positive random variables, the gamma distribution can be applied in a variety of ways. Gamma regression models are thus used in a wide range of empirical applications, such as in the framework of heterogeneous insurance portfolios, which is the most crucial duty of insurers (Krishnamoorthy, 2006), and in hospital admissions for rare diseases where time series are very sparse due to the rarity of events (Winklemann, 2008).

In this review, we examine gamma regression models with covariate-dependent mean and shape parameters. In Cepeda-Cuervo (2001), models that incorporate these two parameters and regression structures are put forth using both conventional and Bayesian methods.

After the introduction, this review includes three more sections. In the next section, the mean-shape re-parameterizations of the gamma distribution are presented. Afterwards, the gamma regression models, where both mean and shape parameters follow regression structures, are presented. Subsequently, the works that have already been done in this field are presented as review of literature.

The Gamma Distribution

A random variable Y is said to follow a gamma distribution if its probability density function is given by the following equation,

$$f(y|\alpha, \lambda) = \begin{cases} \frac{\lambda^\alpha y^{\alpha-1} e^{-\lambda y}}{\Gamma(\alpha)}, & \text{if } 0 < y < \infty \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

Where, $\alpha, \lambda > 0$ and $\Gamma(\cdot)$ denotes the gamma function.

Under such notations, the mean and variance of the Gamma variate is given by,

$$E(Y) = \frac{\alpha}{\lambda} \quad \text{and} \quad \text{Var}(Y) = \frac{\alpha}{\lambda^2} \quad (2)$$

In order to develop a regression model on the basis of this aforementioned distribution, the appropriate reparameterization is done in terms of the mean ($\mu = \frac{\alpha}{\lambda}$) and shape (α) (Cepeda-Curevo, 2001). Then, the modified pdf is given as,

$$f(y|\mu, \alpha) = \begin{cases} \frac{1}{y\Gamma(\alpha)} \left(\frac{\alpha y}{\mu}\right)^\alpha e^{-\alpha y/\mu}, & \text{if } 0 < y < \infty \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

where the random variable can be represented as $Y \sim G(\mu, \alpha)$. Under such parametrization, the mean and variance of Y now become,

$$E(Y) = \mu \quad \text{and} \quad \text{Var}(Y) = \frac{\mu^2}{\alpha} \quad (4)$$

Gamma Regression Model

Let $Y_i \sim G(\mu_i, \alpha)$, $i = 1, \dots, n$, be a random sample of size n . In gamma regression models with constant shape parameter, the mean regression structure is defined by,

$$g(\mu_i) = \eta_i = \mathbf{x}_i' \boldsymbol{\beta} \quad (5)$$

where, g is the link function, $\boldsymbol{\beta} = [\beta_0, \beta_1, \dots, \beta_p]'$ is the vector of mean regression parameters, \mathbf{x}_i is the i^{th} vector value of the explanatory variables and η_i is the linear predictor. Here, $g(\cdot): (0, \infty) \rightarrow \mathbf{R}$ is a real-valued function, strictly monotonic and twice differentiable (McCullagh and Nelder, 1989). Some usual mean link functions which are often worthy of practical consideration in the gamma regression are the logarithm function, $g(\mu) = \log(\mu)$; the identity function, $g(\mu) = \mu$, and the inverse function $g(\mu) = 1 - \mu$. In generalized linear models, the canonical link for the mean is the inverse function.

An extension of the gamma regression models is proposed in Cepeda-Cuervo (2001). In this proposal, the shape parameter is not constant through the observations and is modeled following a regression structure. That is, the mean and shape parameters follow the regression structure,

$$g(\mu_i) = \eta_{1i} = \mathbf{x}_i' \boldsymbol{\beta} \quad (6)$$

$$h(\alpha_i) = \eta_{2i} = \mathbf{z}_i' \boldsymbol{\gamma} \quad (7)$$

where, $g(\cdot)$ and $h(\cdot)$ are appropriate link functions, $\boldsymbol{\beta} = [\beta_0, \beta_1, \dots, \beta_p]'$, $\boldsymbol{\gamma} = [\gamma_0, \gamma_1, \dots, \gamma_p]'$ are, the regression parameter vectors for mean and shape respectively and \mathbf{x}_i and \mathbf{z}_i are their respective explanatory variables for the i^{th} observation. Further, η_{1i} and η_{2i} are the linear predictors. A usual link function in the shape regression structure is the logarithm function.

Review of Literature

Mittlböck and Heinzl (2002) developed upon the several recent attempts to generalise the definition of the R^2 measure onto linear models. The gamma regression model's R^2 measure was examined using two distinct definitions. The sum-of-squares residuals and deviance were found to be connected to these measurements. The so-called unadjusted R^2 measures were found to be potentially significantly exaggerated, depending upon the sample size and the number of covariates included, making the use of adjusted R^2 measures preferable. They further examined a number of previously suggested adjustments for R^2 measures in regression models and showed how they affect the two unadjusted R^2 metrics for the gamma regression model. Best adjustment was determined through simulation by comparing the outcomes with the underlying population data.

Ortega, E. M. M. (2003) examined the use of influence diagnostics in models of generalised log-gamma regression while taking the potential of censored observations into consideration. Appropriate matrices were derived for evaluating the local impact on parameter estimations and predictions from the fitted model under various perturbation strategies. Also examined how censorship affects local impact. The application of these diagnostic methods was explained with an example.

Ortega, E. M. M (2009) altered the generalised log-gamma regression model to account for the potential presence of long-term survivors in the data. With this adjustment, the log-exponential, log-Weibull, and log-normal regression models with a cure rate, typically employed to model such data, became special instances of the generalised log-gamma regression model. The models were utilized in trying to estimate both the surviving fraction, or the percentage of the population for which the event never occurs, and the influence of explanatory variables on the timing acceleration/deceleration of a specific event. Two martingale-type residuals were suggested to evaluate departures from the generalised log-gamma error assumption as well as to identify outlier observations. The normal curvatures of local effect were obtained under several common perturbation schemes and the analysis was illustrated on medical data.

Brown and Dunn (2011) discussed the use of Tobit model and linear regression models to evaluate time use data (TUD). Tobit models presume that the zeros are censored values of an underlying latent variable that is normally distributed and can theoretically take on negative values. Normality is a fundamental presumption in both the linear regression and Tobit models. The Poisson-gamma distribution has a continuous component and a point mass at zero, which stands for the amount of time spent on a particular activity. They described how TUD can be modelled using the Poisson-gamma distribution and generalised linear models. Through the use of a simulated data experiment and TUD, Tobit and linear regression models were contrasted with the Poisson-gamma in terms of the interpretation of the model, the model fit, and the performance of the model. It was discovered that the Poisson-gamma was more theoretically and experimentally sound in most scenarios.

Bossio and Cuervo (2015) gave the Gammareg R-package, which makes it possible to use the R system to statistically compute the class of gamma regressions. A brief explanation of the underlying theory was given, and simulation studies were used to explain how the library is implemented.

Algamal (2018) suggested a gamma ridge regression model (GRRM) as a solution to address the problem of multicollinearity. The shrinkage parameter completely determines how well GRRM performs. They explored a variety of shrinkage parameter selection strategies, also taking their forecasting abilities into account. The results of simulation studies showed that some estimators can significantly improve mean squared error and prediction mean compared to others.

Algamal (2018) developed a novel estimator by combining a gamma ridge regression model with a modified Jackknife estimator. Monte Carlo simulation findings and the real data application indicated that the suggested estimator can provide a significant improvement in absolute bias and mean squared error compared to other competing estimators.

Qasim *et al.* (2018) applied the Liu estimator address multicollinearity in gamma regression models. Estimating the Liu parameter was a significant issue. There are a few estimation techniques for estimating such a parameter that were found in the literature. Some of these strategies were taken

into account in this work, and novel methods for parameter estimation were also suggested. The mean squared error (MSE) was taken into consideration as a performance criterion in the Monte Carlo simulation research that was undertaken to evaluate the performance of the proposed approaches. It was demonstrated that the Liu estimator is consistently better than the ML based on the Monte Carlo simulation and application results, and recommendations were made on the optimal Liu parameter to utilise in the Liu estimator for the GR model.

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GEOLOGICAL PROFILE AND ARID FRUIT PRODUCTION IN BUNDELKHAND REGION

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Introduction

Bundelkhand region comprises of 13 districts out of which six districts lies in south of Madhya Pradesh (Chhatarpur, Panna, Tikamgarh, Sagar, Damoh, and Datia) and seven districts lies in north of Uttar Pradesh (Banda, Chitrakoot, Mahoba, Hamirpur, Jalaun, Lalitpur and Jhansi). Bundelkhand region is largely characterized by shallow red soils, undulating topography, extreme weather conditions and recurrent droughts makes the agriculture in this region more difficult leading to low crop productivity, low crop intensity, and higher soil loss through erosion and runoff due to this extreme weather condition most fruit crops fails to survive. Annual rainfall data and total forest area cover has been mentioned in table below.

| Districts | Annual rainfall (mm) | Total forest area |
|------------|----------------------|-------------------|
| Jhansi | 989.6 ± 218.5 | 4.26 % |
| Lalitpur | 1095.3 ± 257.4 | 11.35 % |
| Jalaun | 902.1 ± 201.2 | 5.37 % |
| Hamirpur | 992.3 ± 211.3 | 4.06 % |
| Mahoba | 1066.5 ± 221.1 | 3.29 % |
| Banda | 1073.4 ± 236.1 | 2.27 % |
| Chitrakoot | 1088.2 ± 252.7 | 18.56 % |
| Datiya | 926.1 ± 217.9 | 5.83 % |
| Chhatarpur | 1142.0 ± 241.1 | 20.06 % |
| Tikamgarh | 1078.3 ± 240.7 | 7.98 % |
| Panna | 1187.7 ± 238.7 | 37.15 % |
| Damoh | 1002.6 ± 243.1 | 35.67 % |
| Sagar | 1190.6 ± 287.3 | 28.19 % |

Source : Dubey et al. 2017, State of Forest Report 2015, Forest Survey of India, Ministry of Environment and Forests.

Scope and Importance of Arid Fruit Culture

Scope of growth of arid fruit industry shall be determined by incentive for farmers, necessity, adaptability of the crops and future scope for expansion depending on the availability of inputs, infrastructure for distribution, marketing system and industrial support. The importance of fruits in providing valuable nutrients, particularly vitamins and minerals in the human diet is well known and according to dietary standard an individual must consume 120-150 g fruits/day. According to present status of area and production of fruits in India, total of 20 to 25 % goes in waste as post-

harvest losses and non-edible portion of the fruits, the availability is put at 46 g/day, which is one of the lowest in the world. To bridge this gap of demand and supply the production will have to be raised through increasing orchard efficiency and by bringing more area under fruit crops. The average yield of fruits in India is around 9.4 tonnes/ha. Yields in most parts of India are well below the proven potentials, Results of research prove that fruit yields can be raised 2 to 6 times than the national average by planting the best available varieties and using improved orchard management techniques. On the other hand, National Commission on Agriculture proposed that the area under fruits should be raised to 6 million ha by 2050 A.D. of which at the most 2.25 million ha would have an access to irrigation. Thus it is evident that there is a need to bring more area under fruit crops. Then the question comes, where is the land available? Traditionally fruit culture has been associated with fertile garden lands with assured irrigation. Since good irrigated lands have already been used, more or less completely, for raising high yielding cereals, commercial crops and horticultural crops and even for ever increasing industries and housing, we have to think of the large areas of marginal lands in arid and semiarid regions of the country with little or no supplementary irrigation. Therefore, fruit culture in arid region is the only hope of the future for feeding the fast increasing population with protective food like fruits.? Table below represent the status of total sown area and total irrigated area of bundelkhand region.

At present most of the arid zones of India has animal husbandry based economy which is not sufficient to provide the required stability in the income of people and therefore, people at large in this region are nomadic in habits. Provision of sustained and stable income to these people shall be sufficient incentive for them to grow fruits. We are now aware that there are a number of fruit crops which have great capacity to stand drought and salinity and still provide good income to growers. For example, the ber which was considered to be a wild fruit a decade back has gained commercial importance in the states of Rajasthan, Gujarat, Haryana and Punjab. A net profit of Rs. 10,000 per ha is not uncommon in ber in Punjab and Haryana. Likewise aonla can give an income of Rs. 20,000 per ha and there is a considerable money in the cultivation of potential fruits like custard apple, tamarind and pomegranate. So all these fruits can also be cultivated in bundelkhand region and one can get better return. Bundelkhand region is characterized by conditions of high aridity. The atmospheric humidity is very low. The rainfall is not only low but erratic and confined to a period from July to September. Summer months are dusty and hot which would not permit proper fruit development. Therefore, the strategy of fruit growing should be such that fruit species selected should complete their reproductive phase well before such stress period and trees should have xerophytic features to overcome drought problem. Plants with such adaptabilities are known and available like ber, lehsua (*Cordia myxa*), kair (*Capparis decidua*), pilu (*Salvadoraoleoides*) and they have great food value as well as industrial uses if only properly exploited. Also the sick saline and alkaline soils, which can't be put under cereal crops owing to greater sensitivity, can be successfully used for fruit crops like ber, date, pomegranate and aonla and even their tolerance can be raised by using resistant root- stocks. Quick development of excellent network of roads and communication deep in rural part of India also provide ample scope of growth of fruit industry in arids which have remained neglected so far.

| Districts | Total sown area (ha.) | Total irrigated area (ha.) |
|-----------|-----------------------|----------------------------|
| Jhansi | 465240 | 223027 |
| Lalitpur | 385426 | 210013 |



| Districts | Total sown area (ha.) | Total irrigated area (ha.) |
|------------|-----------------------|----------------------------|
| Jalaun | 437205 | 191399 |
| Hamirpur | 352531 | 111508 |
| Mahoba | 292021 | 114944 |
| Banda | 422544 | 174065 |
| Chitrakoot | 193321 | 53450 |
| Datiya | 228465 | 136302 |
| Chhatarpur | 511319 | 226581 |
| Tikamgarh | 370642 | 206778 |
| Panna | 297655 | 84420 |
| Damoh | 398648 | 114138 |
| Sagar | 710690 | 236635 |

Source: District wise Land Use Statistics, Ministry of Agriculture, Government of India, May 2018.

Importance of Arid Fruit Culture:

- 1) People inhabiting in these areas are known to suffer from a number of nutritional disorders owing to lower intake of protective foods like fruits and vegetables. Growth of fruit industry in such areas shall definitely increase their intake and help improving health hazards.
- 2) Ensures assured supplemental income to farmers, particularly to the marginal farmers, even in drought years when other fail crops.
- 3) Ensures proper utilization of marginal land, where growing of other food crops is not remunerative and can help in employment generation in such areas.
- 4) Ecological imbalance is a striking feature of Indian arid zone. Growing fruit crops like ber, bael, aonla, custard apple, phalsa, wood apple, karonda, tamarind etc, in such areas shall not only provide sustained economy but help in improving the environment and strike an ecological balance.
- 5) The need for adoption of a multiple land use system such as agroforestry in ecosystem of arid zones involving cultivation of multipurpose trees/shrubs along with agricultural crops in the interspaces has been emphasized for imparting stability to farming systems. The trees generally thought to be as such which provide four F's namely food, fodder, fiber and fruits. Ber, phalsa, wood apple are such potential fruit species which can provide alternatives and a basis for sound farm economy.
- 6) Small scale fruit preservation units can be established to help price regulation. For example technique for the preparation of bye-products of ber like jam, squash, dehydrated ber, ber candy have been standardized at CAZRI, Jodhpur and H.A.U., Hissar. Similarly dehydration units for indigenous fruits like Kair (*Capparis decidua*), Sangri (pods of *Prosopis cineraria*) can be established. Likewise establishments of non-edible oil industry from Pilu (*Salvadoraoleoides*) has ample potential to supplement farmer's income. Likewise processing standards in respect of fruits like jack, carambola, bael, phalsa, jamun, aonla and ber are available for use and can very easily be undertaken at small scale level.

Improvement of underutilized fruit crops in Bundelkhand region

Underutilized crops have greater potential to provide nutritional, social, and environmental benefits to the population residing in Bundelkhand region. Underutilized crops are crops with under-exploited potential for contributing to food security, nutritional security, income generation and environmental services, and are not grown commercially on large scale. Though Bundelkhand

region is considered as very harsh climatically for growing of fruit crops but there are several underutilized fruits species mostly indigenous ones which has wide genetic diversity in Bundelkhand region, such crops can be grown successfully either as rainfed or with supplemental irrigation water such as ber (*Ziziphus mauritiana*), lasora (*Cordia myxa*), Bael (*Aegle marmelos*), karonda (*Carissa carandas*) and fig (*Ficus carica*). Underutilized fruit crops have high nutritional value and excellent production potential. Although India is second largest producer of fruit crop in the world but the post-harvest losses and ever increasing human population causes challenges such as access of fruits to every person at fair price and RDA is yet to be achieved therefore production need to be further increased. In 1978 AICRP on arid zone fruits was started to conduct research on aonla, ber, bael, pomegranate, fig, custard apple, date palm at 12 different centers located throughout the country. As a result technique have been developed for growing of these crops under arid and semi-arid conditions, many underutilized crops has been identified for their edible nutritious fruit in arid and semi-arid region such as jharber, karonda, bael, phalsa, fig, lasora which thrives well in this region. The arid and semi-arid regions of India usually called as dry farming areas and it accounts for 20 percent of the country geographical areas which evenly faces recurrent drought and early withdrawal of rainfall. Malthus postulated that in years of abundance, normally the population goes up and during scarcity there is nothing to eat and that with ever increasing population the people will die of hunger in masses to maintain the nature's balance. Thus we have a challenge before us to feed the ever increasing population with food rich in vitamins and minerals.

Production system under the arid and semi-arid environment faces several biophysical constraints such as poor soil condition, meagre irrigation water resources, hot winds, high solar radiation, very low rainfall, and high temperature. So to survive in this type of climate plants should possess extremely drought hardy characteristics such as deep root system, scanty foliage, mucilaginous leaf, and dormant period during hot summers.

Productivity potential of crop

One of the reason of low productivity in this region is that traditional cultivation in this region is attached with risk of crop failures due to inadequate and ill distributed rainfall with adverse climatic parameters and consequently the fruit production in this region is uncertain and unstable. Since the cultivation in these areas is attached with risk of crop failures the investment in crop management in almost absent. The traditional technology does not even warrant the credit support to the small and marginal farmers who have remained as a neglected unit since ages. Therefore it is necessary to include a high yielding component in the traditional system of cultivation such as introducing high yielding varieties, introducing varieties which are resistant to abiotic stress and early maturing, adopting synthetic fertilizers, adopting drip irrigation and applying insecticide and pesticide to protect crop from for disease and pest infestations.

Role of women in farming sector of Bundelkhand region:-

Women are one of the oldest and foremost workers in agriculture sector of India, since ages they are involved in various field process such as field preparation, digging, planting, irrigation, weeding and harvesting by using their traditional tools such as sickle for harvesting khurpi for weeding spade for making furrow and irrigation canal, often times women are considered as coworker in agriculture sector but at ground level women of rural areas are the main worker in agriculture field, but due to urbanization and race of boosting the economy through urbanization these women are not getting enough pay and also agricultural lands are declining day by day so they are migrating to



cities and prefer to work as a labours in construction site, factories, MSME, to get better pay in order to improve their lifestyle. The women knows the old age technique of farming but at present we are not able to utilize their talent another reason is that farm mechanization technique are becoming more popular and they are also cost efficient and time saving such as digger, planter, harvester, these machines do all these works in couple of minutes whereas humans will take a whole day to do a particular works. Women represent a crucial resource in agriculture because of their role as farmers, labourers and entrepreneurs. Rural women often manage complex households and pursue multiple livelihood strategies, Their activities typically include producing agricultural crops, tending animals, processing and preparing food, working for wages in agricultural or other rural enterprises, collecting fuel and water, engaging in trade and marketing, caring for family members and maintaining their homes Women comprise about 43 percent of the global agricultural labour force and of that in developing countries, but this figure masks considerable variation across regions and within countries according to age and social class. Women comprise half or more of the agricultural labour force in many African and Asian countries, but the share is much less in some countries.

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CULTURE TECHNIQUES OF ASIAN SEA BASS IN POND

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Introduction

Asian Sea bass (*Latescalcarifer*), also known as ‘Barramundi’ is a primarily carnivore finfish. It has been popularly cultured in South East Asian countries and Australia. The Asian Sea bass is aeuryhaline fish thus it can survive from 0 ppt (freshwater) to 35 ppt (seawater) salinity which makes it a most suitable candidate species for culture in both brackish water and freshwater conditions as well as marine cages. Asian Seabass is catadromous (migrating towards sea for breeding) in behavior and it is an economically important food fish in Indo-Pacific countries including India.



Asian Sea bass

Therefore, the intensive production of Sea bass culture in open cages and pond is now being developed and practiced in our country because of its quality taste, white meat and high export market value.

Taxonomy

| | | |
|------------|---|---------------------------|
| Phylum | – | Chordata |
| Sub-phylum | – | Vertebrata |
| Class | – | Pisces |
| Sub-class | – | Teleostomi |
| Order | – | Perciformes |
| Family | – | Centropomidae |
| Genus | – | <i>Lates</i> |
| Species | – | <i>calcarifer</i> (Bloch) |

Local Names of Asian Sea bass in India

'Pandu kappa' in Telugu, 'Koduva' in Tamil, 'KaalANJI' or 'Narimeen' In Malayalam, 'Jitada' in Marathi.

Food and feeding habits

In nature, the sea bass is a carnivorous fish. However, the juveniles are omnivores and it is an opportunistic predator therefore its diet changes with size. Fish ranging in size from 1 to 10 cm can consume algae, diatoms, small fish and shrimp. However, fish larger than 20 cm consume mostly crustaceans and small fishes.

Culture techniques

Asian Sea bass can be cultured in both earthen or lined ponds, Recirculatory aquaculture systems (RAS) and open cages.

Table. 1. The desirable water quality parameters for culture of Asian Sea bass

| S. No. | Parameters | Optimum level |
|--------|------------------|---------------|
| 1. | Temperature | 28 - 32°C |
| 2. | Salinity | 28 – 34 ppt |
| 3. | pH | 7.0 – 8.5 |
| 4. | Dissolved oxygen | < 5 ppm |
| 5. | Ammonia | > 0.1 ppm |
| 6. | Nitrite - N | > 0.01 ppm |
| 7. | Phosphate | > 10 – 20 ppm |
| 8. | Suspended solids | > 2 – 5 ppm |

Sea bass culture in Ponds

Pond preparation

Small pond with a size range of 500 – 2,000 m² is used for Sea bass culture and the water level is maintained at least 1.0 -1.5 m. Suitable sized mesh screen nets (normally 1 mm) should be provided on the inlet side to avoid the entry of unwanted predator fish and crabs. Prior to stocking, the pond can be disinfected by using 30-50 ppm of chlorine for the removal of unwanted predatory fishes, crabs and any microbial contaminants. After pond preparation, the pond water can be fertilized with organic fertilizers to maintain the natural food supply. The water quality of the pond plays an important role in growth performance and survival of Sea bass. The fish growth is mostly affected by acidic and turbid water quality. If the pond water or bottom is acidic, treat it with lime.

Nursery rearing in ponds

The HDPE knotless net hapa (1.5m x 1m x 1m) with mesh size of 2 mm is used for Sea bass nursery culture. The hapa is fixed in earthen pond or open water bodies with the help of bamboo poles. The hapa has provision for opening with zip from the top. This would facilitate handling and feeding. The hatchery produced Sea bass fry (1.5 – 2 cm) can be procured from commercial seed production units and transported under optimal oxygen packing by air lifting or train up to 10 – 12 hrs without any mortalities. After acclimatization, the uniform size fry can be stocked at the stocking rate of 500 – 700 nos / hapa. During the period of nursery rearing, the seed can be fed with slow sinking feed of size range starting from 0.3 – 0.6 mm @ 10 – 12% of body weight daily in three to four times.

Size grading is very essential to reduce the cannibalism and improve the survival rate of Sea bass during the nursery rearing. Therefore, size grading is done at every 5-6 days intervals in nursery period.

Table 2. Size and nutritional composition of Asian Sea bass feed

| S. No. | Fish weight (g) | Feed size (mm) | Crude protein (%) | Crude Fat (%) | Crude Fiber (%) | Moisture (%) |
|--------|-----------------|----------------|-------------------|---------------|-----------------|--------------|
| 1. | 2.5 – 3 | 0.3 – 0.6 | 52 | 12 | 3 – 5 | 11 – 12 |
| 2. | 3 | 0.8 | 52 | 12 | 3 – 5 | 11 – 12 |
| 3. | 3 – 4 | 0.8 | 52 | 12 | 3 – 5 | 11 – 12 |
| 4. | 4 | 1.2 | 45 | 10 | 3 – 5 | 11 – 12 |
| 5. | 4 – 5 | 1.2 – 1.8 | 45 | 10 | 3 – 5 | 11 – 12 |
| 6. | 8 – 10 | 1.8 | 45 | 10 | 3 – 5 | 11 – 12 |
| 7. | 10 – 15 | 2.0 | 45 | 10 | 3 – 5 | 11 – 12 |
| 8. | 15 – 60 | 3.0 | 40 | 10 | 3 – 5 | 11 – 12 |
| 9. | 60 – 150 | 5.0 | 40 | 10 | 3 – 5 | 11 – 12 |
| 10. | 150 – 300 | 7.0 | 40 | 10 | 3 – 5 | 11 – 12 |
| 11. | 300 – 1000 | 10 | 40 | 10 | 3 – 5 | 11 – 12 |
| 12. | > 1000 | 10 - 14 | 40 | 10 | 3 – 5 | 11 – 12 |

Stocking

After nursery rearing (30 – 45 days), the Sea bass fingerlings (4 – 6 g) can be stocked in grow-out ponds at the rate of 10 – 15 fish/m².

Feed and feeding frequency

During the grow-out period, the fish can be fed 3-4 times per day with appropriate sized pellet feed at the rate of 8-10% of their body weight. Depending on fish size, the size of the feed pellets and the frequency of feeding can be adjusted.

Table 3. Feeding rate and feeding frequency for Asian Sea bass culture

| S. No. | Feed size (mm) | Feeding rate (% of body weight per day) | Feeding frequency (meals per day) |
|--------|----------------|---|-----------------------------------|
| 1. | 0.3 – 0.6 | 10 – 12 | 3 – 4 |
| 2. | 0.8 | 10 – 12 | 3 – 4 |
| 3. | 0.8 | 8 – 10 | 3 – 4 |
| 4. | 1.2 | 8 – 10 | 3 – 4 |
| 5. | 1.2 – 1.8 | 6 – 8 | 2 – 3 |
| 6. | 1.8 | 6 – 8 | 2 – 3 |
| 7. | 2.0 | 6 – 8 | 2 – 3 |
| 8. | 3.0 | 4 – 6 | 2 – 3 |
| 9. | 5.0 | 3 – 4 | 2 – 3 |
| 10. | 7.0 | 2 – 3 | 2 – 3 |
| 11. | 10 | 1 – 2 | 1 – 2 |
| 12. | 10 - 14 | 0.5 – 1 | 1 – 2 |



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Harvesting

Asian Sea bass can be harvested when the fish reaches to a size of 600 – 700 gram in 6 – 8 months. Fishing nets (Drag net) can be used for harvest the fish from ponds.

Marketing

Asian Sea bass is highly demand in export market as well as it can be sold in open market at Rs. 400 – 500 per Kg. Consumer preference and lucrative market value make Asian Sea bass is suitable candidate species for brackish water aquaculture.

Conclusion

Asian Sea bass culture is one of the best options for improving the livelihoods and income generation of coastal communities. Brackish water areas such as creeks, lagoons, estuaries, small natural ponds can be well utilized for Asian Sea bass production. Therefore, it can very effectively become a sustainable enterprise for coastal communities as well as increase the food security of the world's population.

IDEAL PROTEIN CONCEPT: A VIEW TO REDUCING FEED COST AND ENVIRONMENTAL POLLUTION

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Introduction

The aquaculture feed industry supplies customers with high-quality protein at a moderate price. Aqua feed is produced with higher protein content than other animal feeds. High protein content in aqua feed is used because fish require less energy to maintain normal physiological functions. Therefore, the feed protein can be converted into food protein by aquaculture production. In aqua feed, the protein is the primary source of nutrients and it is the most expensive component in aqua feed. As a consequence, feed cost is the largest expense among the aquaculture activities, ranging from 50 to 60% of overall operating costs. Fish meal and soybean meal are the main sources of protein used in various aquatic animal diets. Further, the water pollution is one of the major issues that occur worldwide in aquatic environments due to the leaching effect of phosphorus and nitrogen through uneaten feed and faecal matter.

The ideal protein concept is based on von Liebig's " Law of Minimum." It was introduced by Mitchell and Scott on animal nutrition in 1950. The bioavailability of the amino acid profile in ingredients has the greatest impact on feed protein quality. Usually, many ingredients are available with high protein content of up to 50–60% in nature and the limitation of a few amino acid profiles. These ingredients are not properly utilised by aquatic animals. Therefore, this article is designed to discuss the importance and scope of the ideal protein concept in aqua diets.

The importance of protein in fish feed

Protein is needed for normal physiological functions such as tissue repair, tissue formation, growth, reproduction, and maintenance of health in all animals. The dietary protein requirement for fish is significantly higher than for other animals, such as cows, pigs, poultry, etc. Fish need two to four times as much protein in their diet as opposed to terrestrial animals. Fish do not need protein in their diet, they need a balanced amount of essential amino acids. Essential Amino Acids (EAA) can not be synthesised by fish in the quantity needed to meet their needs and must be obtained from the diet. Fish may be able to synthesise certain amino acids on their own as non-essential amino acids, so they do not require to be included in the diet.

The amino acid composition, protein turnover rate and maintenance needs vary for different body proteins. Animals use EAA and NEAA in their feed to synthesise their proteins. The available amount of dietary protein for metabolism depends on the level of EAA supplied. The requirements of fish for some EAA, such as lysine, methionine, histidine, threonine, and tryptophan are at high levels. The development of fish feed that is balanced with essential amino acids is critical to improving dietary protein utilization. An ideal protein is a protein that contains a perfect balance of amino acids for the various purposes of maintenance and production. Therefore, the essential amino acids can be balanced in the feed by the ideal protein concept. It is used as a guideline to establish an essential amino acid profile to formulate the feed. The main application of the ideal protein concept

is the formulation of low protein feed with optimum efficiency of protein utilisation and minimal nitrogenous waste.

Ideal protein concept

Amino acids are provided in the exact amounts needed for maintenance and protein accretion, in which every amino acid is equally limiting. Having all EAA equally limited can decrease the amount of excess amino acids that are oxidized. The "ideal protein concept" has been extensively studied and applied in the formulation of functional diets for terrestrial and aquatic animals to provide a healthy dietary protein. In fact, this definition was based on the premise that feed used for farming practises needs to have an adequate balance of AAs to satisfy the protein synthesis needs of cultivated species(NRC, 2011).

It is a method of ensuring an optimal balance of the amino acids required for optimum performance and effective growth (e.g., height, carcass weight, yield and body composition). It is an efficient way to replace less protein with sufficient amino acids in the feed to fulfil the requirements. It maximises the effective use of protein and reduces production costs, increases farm profitability, and helps to reduce the use of fish meal. It is also applied to reduce the nitrogen pollution arising from fish production. Fish do not have a specific protein requirement, but they do have a specific amino acid requirement, particularly for dietary essential amino acids.

Ideal protein is preparing a fish feed containing protein balanced with the exact amount of each essential amino acid required by a particular fish species. The ideal protein concept is based on the idea that there should be a direct correlation between the whole-body amino acid pattern of the animal and the dietary amino acid requirements of the animal. If the dietary lysine requirement and the whole-body amino acid composition of an animal are known, then the dietary requirement for the remaining indispensable amino acids can be estimated relative to the lysine requirement. There will be no amino acid deficiency or excess amino acids in the feed. The changes in amino acid composition in feed should not alter the relative ratios of amino acids.

The principle of the ideal protein concept is that required amino acids are supplied in specific proportions. The amino acids are efficiently used for maintenance of health, growth, and synthesis of proteins, resulting in maximum feed efficiency and growth. The ideal protein concept in feed formulation needs the essential amino acid requirements of the fish to be met using digestible amino acids rather than total amino acids because fish do not utilise 100% of the nutrients they consume.

Lysine: the reference amino acid

Normally, lysine is the first-limiting amino acid in most feedstuffs. So the requirements for the other indispensable amino acids are expressed relative to the lysine requirement. The concentration of the other essential amino acids is expressed as the percentage of the lysine. The main reasons for selecting lysine as a reference amino acids are as follows:

1. It has only one major function in the animal body for protein tissue deposition. Its requirement is not influenced by another metabolic role.
2. It is one of the limiting essential amino acid, which varies based on the type of feed ingredients and fish species.
3. Its requirement is known more than other amino acids and the analysis of lysine in feed is done without any complications.

Using ideal proteins in aquaculture feeds

The excess amount of protein is added to the fish diet for two reasons.

1. The protein given in the feed may not be easily digestible. So more protein is added to meet the amino acids requirement.
2. If the specific essential amino acid requirements are not known then excess protein is added in the fish feed.

The addition of excess protein to the feed may cause an increase in any other amino acid level in the feed. The fish feed prepared by the ideal protein concept will supply a significant amount of a particular nutrient or nutrients relative to the amount of energy and will also improve the feed conversion ratios and reduce nitrogenous waste.

Benefits of the ideal protein concept

An important benefit of the ideal protein is that it simplifies the establishment of amino acid requirements because the requirements for all EAA can be derived after the requirement for lysine is established. Using an established set of ideal ratios of other EAA to lysine, it is possible to formulate an ideal protein feed without having to independently establish requirements for each EAA. A fish feed can be formulated more economically by minimizing excessive essential amino acids that occur in diets without affecting animal performance. The presence of excess amino acids may cause more nitrogen excretion in the feces. If the ingredient is deficient in particular amino acids (e.g. lysine or methionine), those amino acids can be included in the feed. Therefore, the feed is balanced with all the essential amino acids and without a negative effect on the growth performance.

The supplementation of amino acids can decrease the crude protein level as well as decrease the urinary nitrogen excretion. The amino acid balance concerning the requirements of the fish determines the protein quality of the feed. A feed with a balanced amino acid profile reduces amino acid catabolism and increases protein retention. Meeting the requirements of all amino acids via intact protein sources often results in excessive amounts of dietary protein levels. Inputs of protein represent a significant cost to feed. The ideal protein concept can improve the efficiency of protein utilization and minimizes nitrogenous wastes.

Table. 1 Ideal amino acid profile for teleost fish and penaeid shrimp (NRC,2011)

| Amino acid | Teleost fish | Penaeid shrimp |
|--------------------|--------------|----------------|
| Lysine (Reference) | 100 | 100 |
| Arginine | 82 | 95 |
| Histidine | 35 | 38 |
| Isoleucine | 54 | 48 |
| Leucine | 70 | 81 |
| Methionine | 38 | 48 |
| Met +Cys | 54 | 65 |
| Phenylalanine | 55 | 55 |
| Phe + Tyr | 90 | 100 |
| Threonine | 56 | 67 |
| Tryptophan | 14 | 10 |
| Valine | 61 | 65 |

Table.2 Ideal protein amino acid profile and percentage of amino acid in a channel catfish feed

| Amino Acid | Essential Amino Acid Profile (Expressed as a % of Lysine) | % Amino Acid in Feed (Energy base is 3000 kcal DE/kg of feed) |
|-------------------------|--|--|
| Lysine | 100 | 1.43 |
| Phenylalanine +Tyrosine | 98 | 1.40 |
| Arginine | 84 | 1.20 |
| Leucine | 68 | 0.98 |
| Valine | 59 | 0.84 |
| Isoleucine | 51 | 0.73 |
| Methionine + Cysteine | 45 | 0.64 |
| Threonine | 39 | 0.56 |
| Histidine | 29 | 0.42 |
| Tryptophan | 10 | 0.14 |

Values are taken from NRC, 1993 (National Research Council, 1993. *Nutrient Requirements of Fish*. Washington, DC: National Academy of Sciences.)

Phenylalanine in cellular metabolism is used to synthesize tyrosine.

Methionine in cellular metabolism is used to synthesize cysteine.

Conclusion

A nutritionally balanced formulated diet provides profitable aquaculture production. The formulated diet is mainly focused on the feed protein content and its necessity to fulfill the amino acid requirements of animals for their growth. As a result, feed protein ingredients decide the production cost of feed. Therefore, the ideal protein conceptualization is very useful for preparing the feed, and it may reduce nitrogen pollution in the aquatic environment.

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INLAND SALINE AQUACULTURE: WAY TOWARDS SUSTAINABLE FARMING PRACTICES

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Abstract

The immense growth of aquaculture and its increasing demand has initiated many steps towards the development of new and sustainable production systems. Aquaculture is emerging as a new hope to feed the increasing population at a sustainable rate and Inland saline aquaculture can be considered as one of the major approach towards this. Inland saline aquaculture is a type of land based aquaculture in which saline groundwater is used for the aquaculture farming, this type of aquaculture farming is practiced in many countries along with India including the USA, Israel and Australia. A number of species which are being cultured, or are being potential of having good growth rate in this type of aquaculture system, includes tilapia, Asian sea bass and trout, shrimp and oysters. In some areas the saline groundwater is removed to protect the root zone of plants. Another emerging source of saline groundwater considered, is the coal bed methane gas.

Introduction

Today in the world of emerging population the use of available resources has been optimized and it has become very necessary because of the population pressure in the developing nations also it is very important that the resources should be utilized wisely in a sustainable manner. It has been reported that among some resources which have not been utilized, the land affected due to saline is about 10.1 million ha in India, However, different agencies studied and have given varying estimates about Indian saline area. After that, data and the results from various sources were critically monitored and evaluated at Central soil salinity Research Institute, Karnal, it gave a figure of 7.4 million ha land is a saline land in India. The utilization of such saline land and under lying ground saline water is limited, so it has become very promising for the culture of aquatic animals and plants using the inland sources of saline ground water. When these ground saline water are not utilized it cause rise in the water table in these areas at a very high rate resulting in secondary salinization and water logging conditions which harms and convert the fertile land into an unproductive land. Therefore, it is very necessary to pump the ground saline water which will lower down the water table to a safer root zone this makes the surface soil unaffected.

The reason as to why aquaculture in saline water is considered because the pumping of saline water is very challenging and it is only possible through evapo-transpiration (it is the evaporation of water along with transpiration from surface area to the atmosphere) which is somewhere is very costly, so to resolve this problem and make it economical, aquaculture is considered, in which the large water proportion is evaporated from the ponds along with culturing high income generating fish/prawn/shrimp crops, still it is not as easy because inland saline water differ from fresh, brackish and marine water due to its unbalanced ionic composition.

Inland saline water

Saline groundwater can be found just below the surface and the saline groundwater which is suitable can only be found at nearly 200 m depth. Inland saline ground water is distributed widely in the semi-arid and arid regions where rainfall is less and the rate of evapo-transpiration is high. Considering the salinity and ionic composition Inland saline water vary from location to location. The salinity in the inland saline water ranges from 10-25 ppt with high level of Ca^{2+} and Mg^{2+} , which has resulted in high water hardness. Looking at the positive side saline groundwater has a constant temperature and is rich in nutrients, which do not contain unwanted and harmful marine organisms, results in high productivity. The use of open sea water cause many problem in farming practices , therefore saline groundwater is used, in the marine aquaculture practices the use of inland saline water reduce the cost of pumping the groundwater which helps the farmers to farm in the affected areas and provide economic opportunities. The inland saline waters are mainly located at places where land is cheap and the water is free from any pathogen basically it is found in the remote areas. If the inland saline water are chemically modified it becomes suitable for the growth and survival of the marine species.

Features of inland saline aquaculture:

- Potential source of income from an unutilized or underutilize resource.
- Among the ions present in inland saline aquaculture, the K^+ concentration has a very vital role in maintaining the physiological systems of the aquatic animals.
- This culture system contributes in raising the energy budget and nutritional requirement which is important for sustained growth of the organisms.
- The soil and water in the inland saline states are strongly, moderately and slightly saline in nature, so to resolve this problem aquaculture is considered best, because aquaculture involves the farming or culture of marine, euryhaline, diadromous or freshwater-salt tolerant fish species.
- Seed production of brackish water fishes by using inland saline water will be profitable and will result in good production.

Suitable species for culture in Inland saline waters

Around the world, the saline groundwater cultures different fish species including **euryhaline finfishes** (e.g. *Lates calcarifer*, *Sparus auratus*, *Dicentrarchus labrax*, *Argyrosomus japonicus*), crustaceans (e.g. *Penaeus monodon*, *Litopenaeus vannamei*, *Marsupenaeus japonicus*), molluscs (e.g. *Saccostrea glomerata*), **diadromous species** such as salmonids (e.g. *Oncorhynchus mykiss*), **salt-tolerant freshwater species** such as finishes (e.g. *Oreochromis niloticus*, *Bidyanus bidyanus*) and **crustaceans** (e.g. *Macrobrachium rosenbergii*) Further, Barramundi, *Pangasianodon hypophthalmus* , *Chanos chanos*, *Mugil cephalus*, *Etroplus suratensis*, Common carp are the most commonly cultured fish species in inland saline water.

Status of Indian saline area

Out of a total area of 6.74 million hectares that are affected by salt (including coastal saline soils) in India, about 1.20 million hectares are located in the non-coastal Indo-Gangetic plains in northern India and covering about seven places , including Punjab (1.51 lakh ha), Haryana (2.32 lakh ha), Rajasthan (3.75 lakh ha), Bihar (1.53 lakh ha), Uttar Pradesh (1.37 lakh ha), Madhya Pradesh (1.39 lakh ha) and Jammu and Kashmir (0.17 lakh ha) as presented in Fig 1.

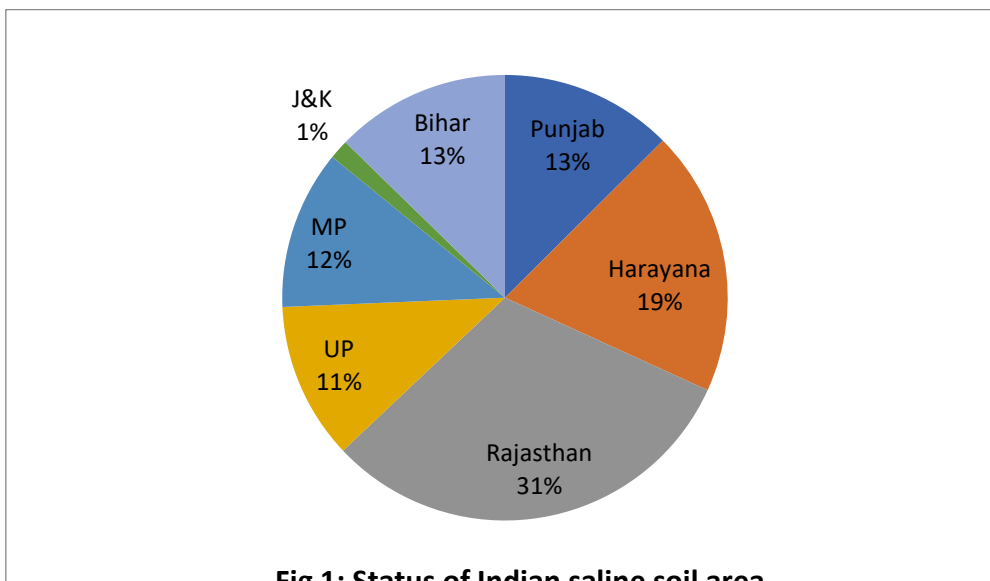


Fig 1: Status of Indian saline soil area

Conclusion and future prospects

The farming of shrimp and fish in the inland saline waters has huge potential. This aquaculture system has been practiced and has got considerable success in various part of world. The farming is considered more profitable as compared to the agriculture land because in this the farmers can yield higher production in a very short period of time. Aquaculture in inland saline water is economical and reduces the production cost. New farming practices can be performed in the inland saline aquaculture system like the Cluster Farming of a large saline area dividing into two clusters and producing two crops per year may result in higher production and profit and also generate employment opportunities for many people.



A STUDY ON THE SOCIO-ECONOMIC PROFILE OF GOAT FARMERS AND THEIR MANAGEMENT PRACTICES IN MALKANGIRI DISTRICT OF ODISHA

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Abstract

Goats are the major source of food security and economic stability for smallholder farmers in rural areas. Women are essential for goat rearing, which promotes family economic prosperity. The present investigation was carried out in two blocks Chitrakonda and Mathili of Malkangiri district of Odisha. About 130 respondents were selected randomly having minimum 10 numbers of goats with 10 years of experience in goat rearing. A total of 18 villages were selected randomly to conduct the study. The animal owners were taken into consideration randomly for collection of data on management practices. The data were noted through interview schedule using the questionnaire method during the month of August 2022 to January 2023. The purpose of the study is to outline the socio-economic situation and management practices of the farmers in Malkangiri district of Odisha.

Keywords: Malkangiri, Native goat, Socio-economic profile

Introduction

There are 148.88 million goats in India overall, making up 27.80% of all livestock. (20th livestock census). In Odisha, there are around 64 lakh goats, with the only recognised breed having about 4 lakh heads (20th livestock census). The remaining native goat populations are less well-known ones like the Ghumusari, Malkangiri, and Narayanpatna populations, or less distinctive ones. In this region of India, the majority of the goat farmers are tribes and underdeveloped people. The condition in Odisha is still poor. For many years, local goat populations have been domesticated to meet the agro-climatic conditions which have contributed to the livelihood of the stakeholders. These populations are distinguished by their high fecundity and high-quality meat. Goat output in this system is comparatively poor due to a lack of inputs, infrastructure, uncertain marketing channels and multiple breeding objectives. The goats are mainly reared for meat purpose making them more economically feasible as they are simple to handle and easily adjust to climatic change. Growth traits of goats directly affect economic potentiality of the poor farmers. The majority of the labour for rearing goats is provided by women and are crucial part of the value chain in the goat sector. Female participation in goat value chains and their benefits that can be obtained from them may be impacted by the bigger financial, social, and institutional restrictions that women face from their male counterparts.

Materials

Information such as agricultural land holdings, number of family members, members engaged in rearing, feeding practices, purpose of rearing animal etc. were collected in order to study socio-economic profile and general management practices of goat. Different practices like breeding, common diseases, medication, vaccination and other special cares adopted by the farmers were recorded in the Questionnaire.



Fig 1: Goats population and their natural vegetation



Fig 2: Goat shed of farmers

Results and Discussion

Housing, feeding and other managerial practices are discussed here. Animals are only kept by farmers overnight. The barn is either next to the farmer's house or it is attached with the house. The dwellings are constructed from bamboo, thatch, and wood that were readily available in the area. Most of the time, thatch was used to make the roofs, but tin sheet was also used occasionally. The sheds' floor is kutcha or uneven. Usually, the shed's vicinity was where the waste was dumped. In most cases, breeding occurred naturally through mating. Without using concentrates or feed supplements, the owners kept the animals in a zero input regime. The animals were raised amongst the natural plants of an open grazing field. The animals were allowed to roam free for grazing from dawn till dusk. Animals weren't fed with fodder that was grown for them. They grazed for 8 to 9 hours daily. Animals had access to enough water, which came primarily from ponds and springs.

Males were often castrated. Animal or shed cleaning wasn't done frequently. For animal therapy, the farmers used locally accessible medicinal sources.

Table 1. General information on socio-economic status of farmers in Malkangiri district

| Sl. No. | Particulars | Districts (Average) |
|---------|--|---------------------|
| 1 | Non-Irrigated Land(acres) | Less than 1 acre |
| 2 | Annual Income(Rs.) | 70,000- 2, 00,000 |
| 3 | Family members | 5-7 |
| 4 | Family members engaged in goat rearing | All |
| 5 | Utility | Meat |

Advantages of goat rearing

Goats in the Malkangiri district are mainly reared for meat purpose. Due to the natural vegetation of hilly terrain, their meat is very tasty and nutritious here. Although milk production is very less here, then also there are lot of benefits of goat milk and hair.



Fig3. Goat meat and milk products

Conclusions

These goats are very hardy and mainly reared in zero input. Generally breeding takes place naturally. Majority of the farmers in this area are marginal land holder. The farmers mainly relied on agriculture & animal husbandry as their source of income and livelihood. The most impoverished facets of society can become financially independent if the public and private sectors take the lead in helping the goats. The availability of resources, such as land, cattle, labour, and off-farm income, within the household determines the economic success of goat husbandry.

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MODELLING AND FORECASTING OF VOLATILITY IN TIME SERIES: A REVIEW ON APPLICATION OF GENERALIZED AUTOREGRESSIVE CONDITIONAL HETEROSCEDASTICITY (GARCH) MODELS

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ABSTRACT

ARCH (Autoregressive Conditional Heteroscedasticity) and Generalized Autoregressive Conditional Heteroskedasticity (GARCH) models are an important class of econometric models used for analyzing and forecasting the volatility of commodity prices in agricultural time-series data. By providing a more accurate and nuanced understanding of the dynamics of commodity price movements, GARCH models can help farmers and agricultural businesses make more informed decisions and manage risk more effectively. In this review, we look at the genesis of GARCH models and how they emerge as a modification of ARCH models. Further, we look at some of the recent developments of such models pertaining to their use in the agricultural field.

Keywords : ARCH, GARCH, econometrics, forecasting, volatility, time-series, risk, GARCH-MIDAS, GJR-GARCH, and E-GARCH

INTRODUCTION

GARCH (Generalized Autoregressive Conditional Heteroskedasticity) models, developed upon Autoregressive Conditional Heteroskedasticity (ARCH) models, are a type of time series model that are used to analyze and forecast the volatility of financial time series data. The key feature of GARCH models is that they allow for time-varying volatility in a time series, which can help to better capture the dynamics of the underlying process.

In agriculture, GARCH models can be used to analyze and forecast the volatility of commodity prices, such as wheat or corn. This is important for farmers and agricultural businesses who need to make decisions about planting, harvesting, and marketing crops based on the expected price movements. The importance of GARCH models in agriculture is that they provide a more accurate and nuanced understanding of the volatility of commodity prices over time. By taking into account the time-varying nature of volatility, GARCH models can provide better estimates of risk and help farmers and agricultural businesses make more informed decisions. Moreover, GARCH models can be used to analyze the relationship between different commodity prices, such as the correlation between wheat and corn prices. This information can be used to develop more effective risk management strategies for agricultural businesses.

The ARCH Model

In a time-series $\{y_t\}$, let ϵ_t denote the error term in the model at time t . To model this as an ARCH process, these ϵ_t are split into a strong white noise process z_t and a time-dependent standard deviation σ_t , which characterizes the typical size of the terms so that,

$$\epsilon_t = \sigma_t z_t$$

Then, the series σ_t is modelled by q^{th} order ARCH(q) model as,

$$\sigma_t^2 = \alpha_0 + \alpha_1 \epsilon_{t-1}^2 + \dots + \alpha_q \epsilon_{t-q}^2$$

$$\sigma_t^2 = \alpha_0 + \sum_{i=1}^q \alpha_i \epsilon_{t-i}^2$$

where, $\alpha_0 > 0$ and $\alpha_i \geq 0$ for all $i = 1, 2, \dots, q$ are the model parameters to be estimated.

The GARCH Model

Now, if one assumes an autoregressive moving average model (ARMA) model for the error variance σ_t^2 , the aforementioned ARCH model becomes a generalized autoregressive conditional heteroskedasticity (GARCH) model.

If p be the order of GARCH terms σ^2 and q be the order of ARCH terms ϵ^2 , then, the GARCH(p, q) model is given as (Bollerslev, 1986),

$$y_t = \mathbf{x}_t' \mathbf{b} + \epsilon_t$$

$$\epsilon_t | \psi_{t-1} \sim N(0, \sigma_t^2)$$

$$\sigma_t^2 = \omega + \alpha_1 \epsilon_{t-1}^2 + \dots + \alpha_q \epsilon_{t-q}^2 + \beta_1 \sigma_{t-1}^2 + \dots + \beta_p \sigma_{t-p}^2$$

$$\sigma_t^2 = \omega + \sum_{i=1}^q \alpha_i \epsilon_{t-i}^2 + \sum_{i=1}^p \beta_i \sigma_{t-i}^2$$

where, y_t is the dependent variable and \mathbf{x}_t is the vector of explanatory variables, both being considered at time t . Further, \mathbf{b} is a vector of unknown parameters and ψ_t is the information set (σ -field) of all information through time t .

Review of Literature

Engle (1982) introduced a new class of stochastic processes called autoregressive conditional heteroscedastic (ARCH) processes to generalize the implausible assumption of constant temporal variance in common time-series models. These processes have a zero mean, are serially uncorrelated, have constant unconditional variances but non-constant variances conditional on the past. The recent past provides information on the one-period forecast variance for such systems. A straightforward scoring iteration was developed, and maximum likelihood estimators were provided for the model. The means and variances of inflation in the United Kingdom were estimated using this model. The chaotic 1970s were found to have a major ARCH effect, and the estimated variances rose significantly. In 2003, Engle was awarded the Nobel Prize in Economics for his work on capturing volatility through ARCH models as described in the 1982 paper.

Bollerslev (1986) proposed a natural generalization of the ARCH process introduced by Engle (1982) to allow for past conditional variances in the current conditional variance. Such models were aptly termed as generalized ARCH or GARCH models. For this novel class of parametric models, stationary conditions and an autocorrelation structure were derived. The estimation and testing of maximum likelihood estimates were also taken into account. Finally, a real-world illustration of the unpredictability of inflation rates was given.

Ramirez and Fadiga (2003) proposed an asymmetric-error GARCH model and evaluated its performance by comparing it with normal-error and Student-t-GARCH models. This was accomplished through three applications that included price predictions for U.S. soybean, sorghum,

and wheat. Applications showed the relative benefits of the suggested model specification when the error component had an asymmetric distribution, and they also offered more accurate probabilistic price predictions for certain commodities.

Tolulope (2022) investigated the pattern and drivers of food price volatility in Nigeria using annual and monthly time series data from January, 2000 to December, 2020. Descriptive statistics, coefficient of variation, ARCH, GARCH, and EGARCH models were used in the data analysis. The analysis found a clustering of volatility from 2000 and 2012, but after that point, the variability in food prices was essentially non-existent. Between the years 2000–2006 and 2007–2012, prices of the majority of food goods increased, with rice seeing an almost treble increase. Food costs continued to rise after this time, clearly exceeding their original levels in 2013–2020. The volatility of food prices in Nigeria was significantly influenced by returns on consumer price index, lending rates, exchange rates, and food price rate. In order to defend producers' interests against unpredictable prices, the study advocated the need for an efficient and long-lasting price stabilisation mechanism that entailed storing strategic or buffer stock.

Otto and Schmid (2022) discussed that GARCH models are often used statistical methods in time-series analysis, notably in finance, to model volatility cluster. In contrast, modelling spatial dependency in the conditional second moments were not previously thought to be of crucial consequence. It was seen that for modelling local clusters of elevated risks, very few models exist in current literature. Their research unified the spatial and spatiotemporal GARCH framework, which also includes all previously published spatial ARCH models, exponential spatial GARCH, and time-series GARCH models, and introduces a novel spatial GARCH process. This spatial GARCH permitted instantaneous spill-overs across all spatial units, in contrast to earlier spatiotemporal and time series models. Estimators were created for this standard modelling framework using a non-linear least-squares method. Ultimately, a Monte Carlo simulation study and an empirical example that focuses on real estate values from 1995 to 2014 across the postal code districts of Berlin were used to show how the model can be used. To demonstrate how locally varying model uncertainties can be captured by the spatial GARCH-type models, a spatial autoregressive model was applied to the data.

Cui et al. (2022) measured investor mood and herding on a monthly basis between the years of 2005 and 2020 using the daily transaction data from the Chinese stock market, as these factors tend to have a significant impact on stock market volatility. Next, two indicators were respectively added to the GARCH-MIDAS model for forecasting volatility. The model confidence set (MCS) test was used to compare their predicting abilities with five GARCH-type models in four crisis times and two up markets. It was discovered that under the GARCH-MIDAS model, herding was a more effective way to explain the long-term component of volatility than investor sentiment. Additionally, both herding and investor sentiment were found to have strong out-of-sample predicting abilities. Finally, investor sentiment outperformed herding in terms of prediction accuracy in up markets whereas herding outperformed investor sentiment during times of crisis. To this end, it was concluded that the effect of investor mood and herding on volatility may be utilised to predict market conditions.

Fu et al. (2022) studied five GARCH models - sGARCH with constant mean, GARCH with skewed student t-distribution (sstd), GJR-GARCH, AR(1) GJR-GARCH, and GJR-GARCH in mean. These models were employed in order to assess the volatility of Apple Inc. (NASDAQ: AAPL) stock returns. Skewed student t-distribution and normal distribution were used to further assess the data distribution of

the five models and capture the shape, skewness, and log-likelihood in AR(1) GJR-GARCH. The distribution of AAPL's closing price and earnings data was examined. It was determined after additional investigation that the AR(1) GJR-GARCH was the best model to explain the volatility of the return series of AAPL.

Viljoen et al. (2022) used a rolling window estimation approach to examine how parameter estimates and volatility forecasts of GARCH models behave over time. The symmetric GARCH, GJR-GARCH, and E-GARCH models were compared. The dataset under study was that of the JSE All-Share index. The index was split into two distinct time periods, a financially stable period and a financially unstable period. Different factors were found to affect how well GARCH models perform, which in turn decides the best suited model for a given set of circumstances. These elements include the forecasting horizon, the financial term, the sample window duration, and the underlying distribution of the log returns.

Wang et al. (2022) suggested a method for predicting garlic prices based on a combination of long short-term memory (LSTM) and multiple GARCH-family models for the nonstationary and nonlinear characteristics of garlic-price series in order to increase prediction accuracy. First, by building GARCH-family models, they aimed to gather information about volatility characteristics, such as the volatility aggregation of garlic-price series. Then, using the LSTM model, the price of garlic was to be anticipated by understanding the intricate nonlinear correlations between the price of garlic and its volatility. On a dataset containing real-world garlic data, the suggested model was implemented. The experimental findings indicated that the combined LSTM and GARCH-family model containing information on the volatility characteristics of garlic price had a typically superior prediction performance than the standalone models. In terms of evaluation indices, such as mean absolute error, root mean-square error, and mean absolute percentage error, the combined LSTM model including GARCH and PGARCH models (LSTM-GP) showed the best performance in predicting garlic price. The greatest results for predicting garlic prices came from the LSTM-GARCH mixed model, which can also support such predictions.

Yahaya et al. (2022) attempted to model and predict the returns and volatility of three prominent cryptocurrencies: Bitcoin, Ethereum, and Binance Coin. The data was taken from the market capitalization that was higher on December 31, 2021, as well as statistics for the time period beginning on November 9, 2017, and ending on December 31, 2021. The three cryptocurrencies datasets were fitted with GARCH models and their performances were evaluated using several model criterion tests. The outcome revealed that the mean of all returns is positive, showing that the price of these three cryptocurrencies had increased throughout the course of the study period. The ARCH-LM test revealed that the volatility of Bitcoin and Ethereum did not exhibit the ARCH effect, however Binance Coin did. The CGARCH model was found to be best for Binance Coin, according to the AIC and log L, which were used to fit the GARCH model to the cryptocurrency. Automatic forecasting was carried out using the chosen ARIMA (2,0,1), ARIMA (0,1,2), and random walk models, which had the lowest AIC for the corresponding currency pairs of ETH-USD, BNB-USD, and BTC-USD. This discovery might help investors identify the distinctive risk-reward features of a cryptocurrency.

Yao et al. (2022) made an attempt to determine whether adding GA-SVM to the GARCH model may increase the predictability of air pollution. The study used central Taiwan as its source of observations because it had the highest concentration of PM_{2.5}. The motivation behind choosing

the country was that in the past three decades, Taiwan had turned into a country with a highly developed economy and a serious PM_{2.5} pollution issue. The empirical implementation of this work was done in two steps. Firstly, it was investigated whether the GARCH effect would be present in the observed PM_{2.5} data. Second, a GA-SVM model was formed and coupled with the GARCH framework to forecast the sample region's 8 h PM_{2.5} concentration. The empirical findings showed that, in terms of MAPE and RMSE, the proposed alternative model beat the conventional SVM and GA-SVM models. These results reflected the original hypothesis that adopting the SVM-based approach model for PM_{2.5} prediction was appropriate and that using the GARCH model can enhance prediction performance. Additionally, in line with what was anticipated, the results further suggested that including the GARCH effect in the GA-SVM model greatly enhances prediction accuracy. According to the authors' understanding, this study was the first to try to incorporate the GARCH impact into the GA-SVM model for PM_{2.5} prediction. It was concluded that the findings strongly recommend regulators and practitioners to consider the GARCH effect in air pollution prediction, if a regression-based model is to be employed in order to improve sustainability.

Shiferaw (2023) made an attempt to capture the dynamic volatility of tea crop prices in Eastern African countries, one of the region's most important cash crops. In order to predict the in-sample value-at-risk (VaR) of tea price returns, he used the Markov-switching GARCH (MS-GARCH)-type specifications with various scedastic functions and error distributions to estimate volatility. From January 1980 to June 2022, monthly tea auction prices (i.e., Mombasa auction) were examined in USD. Using the MCMC method, the MS-GARCH model's parameters were calculated within a Bayesian framework. The results demonstrated that the three-regime EGARCH skewed Student-t model was more effective at estimating volatility. There was no better method for VaR evaluation, although taking into account hetroscedastic functions, fat tails, asymmetry, and regime change was more efficient. Investors were advised to consider using GARCH models with a regime switch in order to control volatility and risk in the East African tea market.

Agbo (2023) focused on forecasting the price of the most important export crops of vegetables and fruits in Egypt from 2016 to 2030. The GARCH and ARIMA models were used in the investigation. According to the findings, ARIMA (1,1,1), ARIMA (2,1,2), ARIMA (1,1,0), ARIMA (1,1,2), ARIMA (0,1,0), and ARIMA (1,1,1) were the best fitted models for determining the price volatility of strawberries, green beans, tomatoes, onions, grapes, and oranges respectively. The outcomes also showed that the ARCH effect only existed in the case of potatoes. The GARCH method was recommended as a substitute. In order to forecast the price of potatoes, the GARCH (1,1) model was proven to be more accurate.

Enumah and Adewinbi (2023) considered the timeframes from January 2015 to July 2022 and studied the uses of symmetric GARCH, asymmetric GJR-GARCH(1,1) and E-GARCH(1,1) models to explain the dynamics of the Polish PLN/EUR and PLN/USD exchange rates. Their findings indicated that the USD rate is more vulnerable to market changes and outside factors than the EUR rate. The volatility of both rates were also found to last for some time after a market crisis, with the EUR rate taking longer to stabilise. It was discovered that the E-GARCH model was the best model out of the three that were taken into consideration, based upon their AIC and BIC values.

Oyinebifunet *al.* (2023) aimed to find a trustworthy GARCH model for each economic indicator in Nigeria, such as the price of crude oil, the consumer price index, the exchange rate, and the inflation rate. The data sets used were simulated data sets and monthly secondary data. The secondary data

was covered from January 2004 to December 2020. For the purpose of identifying volatility in research data, the beta volatility coefficient (BVC) model was proposed. Robust models for each variable were discovered using a proposed method called Beta Volatility Coefficient (BVC) and Model Accuracy Measure (MAM) for the four sample sizes: 50, 100, 150, and 200. According to the outcomes of the asymmetric models, leverage influence existed. A statistically significant value for each of the variables was found. The results of the BVC of the symmetric and asymmetric models at the various sample sizes showed that the inflation rate series was 11% more volatile than the crude oil price and exchange rate series, and when the sample size is large, the consumer price index was found to be 55% more volatile than the crude oil price and exchange rate. The identified reliable models for the forecasting of the crude oil price series, the inflation rate series, the exchange rate series and the consumer price index series were the asymmetric E-GARCH (1, 1) model, the symmetric GARCH-M (1, 1) model, the symmetric GARCH (1, 1) model, and the asymmetric E-GARCH (1, 1) model, respectively. An advancement over past research was that the asymmetric GARCH model was found to consistently beat the symmetric GARCH model for exchange rate and consumer price index. For the price of crude oil and the rate of inflation, the symmetric GARCH model performed better than the asymmetric GARCH model. Predictions for each variable were made for the period of January 2022 to December 2024 using the models that were deemed to be reliable.

Ramliet *al.* (2023) aimed to evaluate the market value and relative volatility of two relatively common cryptocurrencies, *viz.*, Ethereum and Bitcoin. The daily prices of Ethereum and Bitcoin were analyzed using GARCH models. Since it is more accurate than the other GARCH (p,q) model, the GARCH (1,1) model is used. The study's findings lead it to the conclusion that Ethereum's volatility is more likely than Bitcoin's to last over the long term. However, compared to Bitcoin, Ethereum's volatility is less enduring in the short term. As a result, Ethereum is far more profitable over the long term than Bitcoin, while Bitcoin is significantly more profitable over the short term.

Alaoet *al.* (2023) studied the potential effect of fluctuations in oil prices in the output of industrialised and developing countries. It was seen that the transmission mechanism of oil price shocks frequently exhibit nonlinearity due to factors like business cycles and changes in policy. The influence of oil price volatility on production growth in the Group of Seven (G7) nations was considered, together with the relationship between oil price volatility and output growth. In order to achieve this, monthly data for the G7 nations' industrial output indices and West Texas Intermediate oil price throughout the period 01/1990 to 08/2019 was analysed. Methods used included symmetric empirical analysis, DCC, cDCC-GARCH, GJR-GARCH, FIEGARCH, HYGARCH, and cDCC-GARCH. The results showed that the magnitudes of the asymmetric (positive and negative) effects of oil price shocks on output growth differed significantly. The findings also showed that the current conditional volatility of the output growth of the G7 nations is significantly influenced by lagged volatility and prior news. It was concluded that the asymmetric GARCH models outperformed the symmetric GARCH models, the volatility of oil prices had an asymmetric impact on output growth in the selected economies, and it is extremely persistent and clustering.

Charef (2023) made an attempt to forecast the financial series of the exchange rate in Tunisia, namely the USD/TND, the EUR/TND, and the YEN/TND, for a daily frequency spanning from 2015 through 2019. The fusion of modelling techniques, such as the GARCH model and the Artificial Neural Network (ANN), were described in order to form a hybrid GARCH-NN method. The empirical findings demonstrated that the hybrid model (GARCH-NN) performed better and was more



effective than the two models that were utilised. In fact, this method was found to combine the benefits of two methodologies to produce a result that is more in line with what policymakers anticipate in the exchange market when making decisions. Results further indicated that the proposed model performed better than the conventional linear autoregressive model, suggesting that it may be used instead.

Yadav *et al.* (2023) used the dynamic conditional correlation generalised autoregressive conditional heteroscedasticity (DCC-GARCH) model to empirically estimate the volatility spillover transmission in the Indian equity market represented by the Sensex from the world economies composite index (Euro Stoxx 50). They used secondary data collected on a weekly basis between 1 April 2012 and 3 March 2022. The conclusions showed that there existed a short-term spillover effect from international markets to Indian stock markets. It was further suggested on this basis that investors can invest in the Indian stock market for a long time as there is no volatility transmission or spillover from the Euro and Nasdaq, but investing in the Indian stock market in the short term is risky owing to the volatility impact present in all developed stock markets.

Khan *et al.* (2023) studied the disturbance in financial markets due to effects of COVID-19 pandemic. The market volatility and asymmetric behaviour of Bitcoin, EUR, the S&P 500 index, gold, crude oil, and sugar during the COVID-19 pandemic were examined. On the daily time series returns data covering the period from 27 November 2018 to 15 June 2021, the GARCH (1, 1), GJR-GARCH (1, 1), and EGARCH (1, 1) econometric models were applied. The empirical results indicated that throughout the COVID-19 epidemic, there existed persistently high levels of volatility in all financial markets. Additionally, during the course of the epidemic, the S&P 500 index and crude oil were both found to exhibit significant positive asymmetry. Aside from this, the findings also showed that EGARCH is the best model to capture the volatility of the financial markets before to the COVID-19 pandemic, while each GARCH family equally modelled the volatility of the six financial markets throughout the COVID-19 era and for the entire period.

AN INTRODUCTION TO NUTRITIONAL AND MEDICINAL VALUE OF PAPAYA - A REVIEW

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Introduction

Carica papaya Linn is commonly known as papaya in English, Papita in Hindi and Erandakarkati in Sanskrit. Caricaceae family has four genera in the world. There are four species in India that belong to the genus *Carica* Linn, with *Carica papaya* Linn being the most frequently cultivated and well-known species. Papaya tree is basically a short lived tree. Due to its buttery flavour and unique look, it was once regarded as an exotic fruit. The papaya was the first GM fruit that people ate for its health benefits and nutritional value. The plant is native to tropical America and it was introduced to India in 16th century. The plant is known by its weak and unbranched soft stem yielding white latex and is crowded by a terminal cluster of large and long stalked leaves. Papain is a proteolytic enzyme that is a component of the milky papaya latex and has many important pharmaceutical and industrial applications. It is used in food biotechnology to produce the chewing gums and several dehydrated pulses and beans and in the textile industry for degumming silk & softening wool. Papain is also used as a component of soap, shampoo, toothpaste and several skincare products. The medicinal properties of papain include its use as an enzymatic debridement for necrotic tissue in burns, ulcers and other wounds and also for the preparation of many vaccines and drugs for various digestive ailments.

Botanical Classification

| Domain | Flowering plant |
|----------------|---------------------------|
| Kingdom | Plantae |
| Sub Kingdom | Tracheobionta |
| Class | Magnoliopsida |
| Subclass | Dilleniidae |
| Superdivision | Spermatophyta |
| Phyllum | Steptophyta |
| Order | Brassicales |
| Family | Caricaceae |
| Genus | <i>Carica</i> |
| Botanical Name | <i>Carica papaya</i> Linn |

Botanical Description

Plant

Papaya is a single-stemmed perennial tree having about 20-30 feet height. The leaves are very large, palmately lobed or deeply incised with entire margins and petioles of about 1-3 feet in length. In papaya, stems are hollow, light green to brown in color with a diameter of about 8 inches and it bears several prominent scars.

Fruit

The fruit of papaya is big, oval shape and sometimes resemble melon by having a central seed cavity, so also known as pepo like berry. Fruits are borne axillary on the main stem singly & sometimes in small clusters. Fruits weigh around 0.5 to 20 lbs and are green unlike ripe, turning yellow or red orange. It's flesh is yellow-orange at maturity. The edible portion is surrounded by the large central seed cavity. Plants begin bearing fruits in 6-12 months.

Flowers

Papaya plants are dioecious or hermaphroditic, which produce only male, female or bisexual flowers. Papayas are also called "trioecious" i.e. separate plants bear either male, female, or bisexual flowers. The female and bisexual flowers are waxy, white and borne on short peduncles in leaf axils, along with main stem. The position of ovary is superior. Before opening, bisexual flowers are tubular shaped whereas female flowers are pear shaped. As desirable fruits are produced by bisexual plants and also are self-pollinating so in most of the cases they are preferred over female/male plants. Male papaya is distinguished by the smaller flowers borne on long stalks. Female flowers of papaya is of pear shaped when unopened whereas, bisexual flowers are cylindrical.



Fig.1 Plant



Fig.2 Fruit



Fig.3 Flowers

Papaya is a common man's fruit, which has a high nutritive value. Lower in calories and comparatively rich in natural vitamins and minerals. Papaya is the first among the fruits for vitamin C, vitamin A, riboflavin, folate, calcium, thiamine, iron, niacin, potassium and fibre. The low calories content (32 kcal/100g of ripe fruit) makes this a favourite fruit of people. It has more carotene compared to other fruits such as apples, guavas, sitaphal and plantains, which help to prevent damage by free radicals. Unripen green papaya can be used as a vegetable, although it does not contain carotene but except that all other nutrients are present. It is also used in making salads, pies, sherbets, juices and other confections. Consumption of papaya regularly ensures a good supply of vitamin A and C necessary for good health, eyesight and can help to prevent early age blindness in children.

Antimicrobial

The seed of papaya has antimicrobial activity against *Trichomonas vaginalis* trophozoites. The report suggests the use of papaya seed in urinogenital disorder like trichomoniasis with care to avoid toxicity. The seed and pulp of papaya was shown to be bacteriostatic against several enteropathogens such as *Bacillus subtilis*, *Enterobacter cloacae*, *Escherichia coli*, *Salmonella typhi*,

Staphylococcus aureus, *Proteus vulgaris*, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* by the agar cup plate method.

Anthelmintic

The air dried papaya seeds given as elixir with honey had an effect on the human intestinal parasites. The consumption of papaya is a cheap, natural, harmless, readily available curing and preventive strategy to prevent against intestinal parasitosis, especially in tropical areas. Benzyl-isothiocyanate, present in the seeds is the main anthelmintic.

Anti-amoebic

The cold macerated aqueous extract of matured papaya seeds has shown anti-amoebic activity against *Entamoeba histolytica*.

Antimalarial

The petroleum ether extract of rind of raw papaya fruit shows a significant antimalarial activity. There might be a significant commercial potential in extraction of the active element from the plant, which grows abundantly throughout the tropics and the rind of papaya is discarded as waste, whereas it can be exploited for antimalarial activity.

Antifungal

The latex of papaya and Fluconazole has synergistic impact on inhibition of the growth of *Candida albicans*. This effect results in the cell wall degradation partially. Latex alone is most effective on *C. albicans*, when added to a culture during the exponential growth phase and approx 60 percent of it was achieved.

Anti-fertility

The anti-fertility effect of *Carica papaya* was investigated by feeding an adult and along with adult, a pregnant rat with separate components of the fruit. No even a single attempt was made to forcefully feed the animal and the result identified that the unripe fruit interrupts with the estrous cycle and induces the abortion. This effect vanished when the fruit became over ripened. The chloroform extract of the *Carica papaya* seeds induced long term azoospermia in languor monkey. Papaya also shows the anti-implantation and abortifacient effect.

Immunomodulatory activity

Papain induces human eosinophils to degranulate and to produce superoxide anion. The E-64 inhibitors abolished the activation by papain suggesting that the protease activity is required to trigger eosinophil response. It is likely that this action in eosinophils is mediated by protein G linked receptor. As it stands it appears that bromelaine and papain depending on the target cell display opposite effects.

Anti-hypertensive

Papaya leaves decoction can be used as an anti-hypertensive agent. A study on villagers of Agboville located at 80 km of Abidjan (West Africa), showed the hypotensive activity of papaya plant.

Conclusion

Papaya is the first among the fruits for vitamin C, vitamin A, riboflavin, folate, calcium, thiamine, iron, niacin, potassium and fibre. The low calories content (32 kcal/100g of ripe fruit) makes this a favourite fruit of people. The seed of papaya has antimicrobial activity against *Trichomonas vaginalis* trophozoites. The report suggests the use of papaya seed in urinogenital disorder like

trichomoniasis with care to avoid toxicity. The air dried papaya seeds given as elixir with honey had an effect on the human intestinal parasites. The consumption of papaya is a cheap, natural, harmless, readily available curing and preventive strategy to prevent against intestinal parasitosis, especially in tropical areas. The petroleum ether extract of rind of raw papaya fruit shows a significant antimalarial activity. The latex of papaya and Fluconazole has synergistic impact on inhibition of the growth of *Candida albicans*. The anti-fertility effect of *Carica papaya* was investigated by feeding an adult and along with adult, a pregnant rat with separate components of the fruit. The chloroform extract of the *Carica papaya* seeds induced long term azoospermia in languor monkey. Papain induces human eosinophils to degranulate and to produce superoxide anion. The E-64 inhibitors abolished the activation by papain suggesting that the protease activity is required to trigger eosinophil response. Papaya leaves decoction can be used as an anti-hypertensive agent.

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PHYTOMELATONIN : A NEW PLANT HORMONE FOR PLANT DEVELOPMENT AND STRESS TOLERANCE

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Melatonin, a well-known mammalian hormone is not just regulate circadian rhythm, and promote sleep in humans and animals but is also involved in multiple physiological actions in plants. Regulating melatonin production in plants could be a promising strategy for improving crops' resilience to stress in the era of climate change.

Melatonin, a well-known mammalian hormone, was originally discovered in 1958 when Aaron Lerner isolated it from the bovine or cow pineal gland. Initially it was thought to be exclusively a product of the vertebrate pineal gland which is located in the middle of the brain, functions with the rhythms of the sun, and is essential for good sleep. Due to melatonin's ancient evolutionary background, it was then found that several organisms outside the animal kingdom also possessed it. Melatonin has been detected in both proteobacteria and photosynthetic cyanobacteria, suggesting that it first appeared in bacteria. Scientist argued that the ability of present day higher animals to produce melatonin is a process inherited through evolution from their ancestors i.e. ancient bacteria; and during this process the evolved organelles retained its melatonin synthesizing capability. As a result, all species between bacteria, plants and humans probably likewise engage in the production of this multifunctional molecule. Studies reported that melatonin was found in many bacteria, algae and in several species of fungi and in higher plants as well. In the year 1993, melatonin was possibly detected in the Japanese morning glory (*Pharbitis nil*) but these data was reported in 1995. In the same year, its presence was demonstrated in a number of edible plants. Since then, it has been identified in many plants: fruits like bananas and grapes and grains such as rice, wheat, barley, and oats are rich in melatonin. Considerable progress has been made in revealing the melatonin biosynthetic pathway in plants. The amino acid tryptophan is the precursor for its biosynthesis, and the steps of enzymatic reactions are somewhat similar in both plants and animals.

In animals, this endocrine hormone act as an antioxidant and signaling molecule and regulate a number of physiological functions. The primary function of melatonin is regulation of the circadian rhythm, mood, sleep and body temperature, it can suppress the libido by inhibiting the secretion of luteinizing hormone and follicle stimulating hormone from the anterior pituitary gland. Melatonin lowers the levels of the hormone leptin, which controls appetite and satiety and can also regulate the immune system. In plants, this molecule helps them respond to the light and dark cycles, or photoperiods. Melatonin participates in a wide range of physiological functions such as growth, rooting, seed germination, photosynthesis, osmoregulation, and protection against abiotic and biotic stressors. It is primarily considered an antioxidant and scavenges reactive oxygen and nitrogen species (ROS and RNS) and other free radicals and oxidative molecules in plant cells. Identification of the first plant melatonin receptor opened the door to this molecule being considered it as a new plant hormone and its multiple actions also point to it being an important master regulator of redox homeostasis in plants. Role of melatonin as a regulator of the expression

of enzymes and other elements related to the redox network has been demonstrated. Melatonin regulates oxidative stress and ROS in plants, through redox enzymes, including SOD, CAT, POX, ASX, and GR, and the metabolites ASC, GSH, and others, in a similar way to that which occurs in animal cells. Melatonin acts as a biostimulator in situations of abiotic stress, it acts as a regulator against plant pathogen attacks, both fungal and bacterial, with a key organizing role in the pathogen response in which ethylene, ABA, salicylic acid (SA), and jasmonic acid are usually involved. Melatonin performs as an antisenesescence agent.

Research evidence also indicates that melatonin also acts as an enhancer or protector of photosynthesis and stomatal conductance, upregulating many elements of photosystems, electron transporters, and ATP synthesis. Exogenous application of melatonin promoted root organogenesis, such as lateral root and adventitious root development, in various plants, including rice, cucumber, and Arabidopsis. A study suggest that exogenous melatonin application enhances the drought priming induced cold tolerance by modulating sub-cellular antioxidant systems and the level of the plant hormone abscisic acid in barley. Melatonin-treated plants show an increased net photosynthetic rate, transpiration rate, stomatal conductance, quantum yield of photosystem, and photosynthetic electron transport rate. Melatonin is also involved in secondary metabolism, where it induces anthocyanin biosynthesis and the production of flavonoids. It shows great potential as a biotechnological tool to alleviate biotic and abiotic stress, delay senescence, and conserve the sensory and nutritional quality of postharvest horticultural products, which are of considerable economic importance worldwide.

Phytomelatonin is an emerging molecule with pleiotropic effects and many diverse activities in plants. Different plant species possess varying contents of melatonin, and there has been a quest to identify the plants with high contents of melatonin for application in agriculture and for its potential use as a nutraceutical for human health and wellbeing. There has been a great deal of interest in the application of exogenous melatonin in agriculture to obtain more stress-resilient crops and better postharvest conditions in a climate change scenario. Interestingly, the application of phytomelatonin as a biostimulator in crops, in contrast to synthetic melatonin, could be a sustainable approach and has been shown to act as natural biostimulating agents against biotic and abiotic stress. Taking into account that phytomelatonin-rich aromatic and/or medicinal plants could be a potential source of this multifunctional molecule Bacteria and photosynthetic cyanobacteria could be genetically or metabolically engineered to overproduce the phyomelatonin content for exogenous applications in agriculture. Finally, the regulation and improvement in the production of melatonin in crop plants could lead to an increase in crop production in agriculture and improved general health for humans who consume these crops.

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FOCUS AREAS OF PROMOTION OF MILLETS

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Millets have been a neglected crop (Kumari and Kumar 2020), for over decades is an undisputed fact. Millets are cultivated in large acreage by resource poor (Kumar et al., 2018), living and striving in the challenged agro-ecosystem (Behera, 2017). In Madhya Pradesh majority of the millets are grown in nutrient poor shallow and skeletal soil under rainfed condition (Kumar et al., 2018; https://www.millets.res.in/books/Minor_millets_in_South_Asia_1407.pdf) by farmers.

Millet sub sector may be viewed under the following four sub heads to get the clear picture for developmental priorities.

- Production system
- Constraints
- Marketing
- Processing and packaging

Production system

As mentioned earlier, millets are grown in complex diverse risk prone (CDRP) farming system (Saxena et al., 2018). This system is predominated by the socio-economically very poor farming communities (Behera, 2017). Generally, millets are cultivated in nutrient poor, shallow and skeletal soil under rainfed condition.

The characteristics of the farming situation of millet crops are very important for the analysis of the production and productivity. The growth of any crop raised on soil that is poor in nutrients can be expected to have low indices in all the growth parameters (Selim et al., 2020). A stunted plant with low nutrient availability produces less (Uchida, 2000), is a universal fact. Thus, the production and productivity are compromised. It is well acknowledged the importance of soil depth and rhizosphere (Hao et al., 2021) on plant growth and yield (Xiong et al., 2021). However, when a crop is cultivated in shallow soil with skeletal character, the root growth and the dynamics of rhizosphere is constrained. Such a situation has a negative impact on the yield parameters. Rainfed condition is another factor that decides plant growth and yield performance (Sivakumar and Surendar, 2020).

The impact of delay in rain, early withdrawal, or a dry spell (Seleiman et al., 2021) during crucial crop growth stages on the overall yield of any crop is well acknowledged in scientific world. Thus, such a diverse situation is complex in the prominent millet growing areas which makes it risk prone (Reynolds et al., 2015). Finally, the uneconomical yield and incompatible sustenance drives further to a stage where they resort to gradually abandon millet for an alternative during the next cropping season. This is reflected by a shrinkage in the acreage of millets in recent years (Prabhu et al., 2022).

Constraints

Any production system is an economic activity (Dudek, 2016). There is an input of family labour, resources at the disposal of the household and shared assets by especially small and marginal farmers (Nayak et al., 2018). Among millet farmers inflow cash is a major constraint (Wanga et al., 2022). Lack of cash and accessible to credit due to their poor socio-economic situation, millet is not grown seriously with proper soil nutrient application (Toukara et al., 2020), management of weed

and soil moisture during the crop growth stages. The resultant yield is usually not encouraging to bring cheers to the millet farmers (Saxena et al., 2018).

Cash is the outcome of a transaction of a goods or commodity (Shapley and Shubik, 1977). If one revisits the production system or the agro-ecosystem of millets, in the existing practices the production seldom has marketable surplus (Bisht et al., 2020). Thus even if selling happens, its always in low volume. Millet is neither a cash crop nor is under existing MSP regime (<https://reliefweb.int/report/india/mainstreaming-millets-policy-brief-2-case-including-all-varieties-millets-under-minimum-support-price-msp>). This is another constrain besides low productivity. Millet farmers in MP are being predominantly tribal farmers (Reddy, 2018) of small and marginal category. They either barter away their produce or sell to local traders at a throw away price. Millet for them is neither a profitable venture nor assist in sustenance (Orr et al., 2020), yet they grow it because of their tradition or limited options (Gururani et al., 2021).

Marketing

Marketing requires a product and a buyer (<https://www.cim.co.uk/media/4772/7ps.pdf>). Here as mentioned, millet as a product is always in low volume available as marketable surplus among the farmers. The next disadvantageous situation is that millet buyers are not many therefore lack competitive pricing. In the absence of organized millet farmers group, the commodity to be transacted or traded will remain in low quantity (<https://www.goya.in/blog/in-tamil-nadu-women-sustain-the-revival-of-a-grain-orphaned-by-the-green-revolution>) which means poor bargain and low-price realization to the farmers. Millet farmers live scattered along the foothills or on the hilltop (Bhattacharya and Gadgil, 1993), usually isolated and distantly connected with the main lane of the trade. Here, middlemen fill the space and take advantage of the situation (Das, 2020).

Processing and packaging

Millet especially minor millets are grown organically (Pramitha et al., 2022), by default. The financial constrains compel majority of the Millet growers to restrain from application of chemical fertilizers (Behera, 2017) in their millet fields. Usually, investments on chemical fertilizers are done when the returns are higher (Duflo et al., 2011). However, returns in the form of grain yield and cash returns from millets remained discouraging.

Having known from the statistics of chemical fertilizer consumption in such agro-ecosystems for years especially in MP (Bora, 2022), it is easier to identify these geographical areas as technically organic instead of relying on the costly and time taking organic certification process. This process is followed in Northeastern States in India, the reason for delay in replicating the same process in identified areas in MP is unknown. Government of Madhya Pradesh may seriously think on these lines with strategic policy initiatives.

A small initiative towards processing of millets in Dindori district of MP is widely acknowledged (https://apeda.gov.in/milletportal/files/Madhya_Pradesh_Millet_Value_Added_Products_Catalogu.pdf) and appreciated. However, much more must be done from the learning involving different players and partners. The Department of Food Science and Technology, JNKVV Jabalpur has done quality research on millet processing, but the outcome is yet to be downloaded to the community and industry. Packaging is highly specialized area and very important component of marketing, branding and trade (Agariya et al., 2012). Indian Institute of Packaging needs to be drawn into millet sub sector.



The millet sub sector has a basket full of challenges and opportunities (<https://www.fao.org/3/i6583e/i6583e.pdf>). The crop has a direct influence on the socio-economy of the poorest of poor (Behera, 2017) and also the undistributed agro-ecosystem (Pramitha et al., 2022). The sector needs to develop and demands involvement of numerous players. Here comes the role of Non-Government Organization, Civil Societies and Startups. They all have different roles to play.

Research Institutions may plan research programme at least with ten year timeline especially on the individual components of production of millets. However, in the race to increase the production and productivity, introduction of chemical fertilizers may be avoided in these naturally organic regions. Majority of the millet growing areas are in the hostile regions. The scientific team placed millet growing regions are comparatively less privileged. Recognition and incentives are also comparatively lesser here than those in the well endowed research stations or agriculturally prosperous regions. The strategic points need a rethink for strengthening research and development on millets.

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