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Co-production of hydrolytic enzymes using gram waste and its optimization through the OVAT approach for *Nesterenkonia* sp. K-15-9-6

Prashant S. Arya, Shivani Yagnik Raval, Vikram H. Raval*

Department of Microbiology and Biotechnology, School of Sciences, Gujarat University, Ahmedabad-380009

*Email: vhraval@gujaratuniversity.ac.in; vikramhraval@gmail.com

ABSTRACT

Agro-industrial and food processing wastes need proper treatment if sustainability is to be achieved. This study proposes a systematic approach to convert gram waste into valuable products (hydrolytic enzymes) via submerged fermentation (SmF) using *Nesterenkonia* sp. K-15-9-6. The co-production approach, involving the synthesis of multiple enzymes in a single medium, offers efficiency gains with cost reduction. To enhance the yield of enzymes, the key parameters were optimized, including incubation period (24-120 h), pH (7.0-11.0), gram waste concentration (2.0-10.0g%), inoculum volume (3.0-15.0%v/v), medium volume and NaCl (0.0-15.0%w/v). The research finding indicated that incubation time, 48h; pH, 9.0; gram waste, 8g%; inoculum volume, 5%v/v; medium volume, 75mL and NaCl concentration, 2.5%w/v were optimum for co-production of hydrolytic enzymes. The maximum protease (129 U/mL), xylanase (5.12 U/mL), cellulase (5.66 U/mL), amylase (5.89 U/mL), and lipase (4.99 U/mL) production was observed under optimized conditions. In summary, this work highlights the potential of *Nesterenkonia* sp. K-15-9-6 for co-producing hydrolytic enzymes and sustainable managing of gram waste.

Keywords : Gram waste, Co-production, Hydrolytic enzymes, *Nesterenkonia*, Sustainable Waste Management

INTRODUCTION

The demand of biocatalysts has been significantly increased in recent years, prompting researchers to explore innovative and cost-effective approaches for production of biocatalyst (Sharma *et al.*, 2022). Co-production, a strategy involving the simultaneous synthesis of multiple enzymes, emerges as a promising avenue for enhancing production yield and reducing production cost (Kaur *et al.*, 2020). An intriguing method entails the utilization of gram waste as an economical substrate for

the co-production of hydrolytic enzymes. Gram waste, encompassing residues from gram crops like chickpeas, husks, lentils, peas, and other by-products, plays a substantial role in global agriculture and serves as a considerable biomass resource for the biosynthesis of various biomolecules (Prakasham *et al.*, 2006). Gram waste offers several advantages as a substrate, being abundant, cost-effective, and displaying diverse biochemical compositions conducive to the growth of enzyme-producing microorganisms. Moreover, the nutritional content of gram waste fosters an

environment favorable for the synthesis of hydrolytic enzymes, making it an ideal candidate for co-production processes. This waste not only presents environmental challenges of safe disposal but also offers a sustainable solution via biosynthesis of multiple hydrolytic enzymes (Rodríguez Couto, 2008; Suganthi *et al.*, 2011).

Usually, enzyme production has relied on conventional sources such as microorganisms, plants, and animals. Among the different group of bacteria, halophilic bacteria have adapted to thrive and function optimally in conditions with high salt concentrations (Raval *et al.*, 2014; Gunde-Cimerman *et al.*, 2018; Raval *et al.*, 2022). The combination of halophilic bacteria and agro-food waste in submerged fermentation for enzyme production presents a synergistic approach aligning with cost-effectiveness, reduced contamination risk, and the sustainable utilization of waste materials. This approach holds implications for various industries, including biotechnology, food processing, and waste management (Sharma *et al.*, 2023).

Conversely, traditional methods often encounter challenges related to high production costs, limited scalability, and environmental impact. The pursuit of sustainable alternatives has intensified the exploration of unconventional substrates, leading researchers to investigate agro-industrial residues (Arya *et al.*, 2022a). However, co-production offering distinct advantages. Firstly, it maximizes resource utilization, ensuring a more efficient and sustainable process. Secondly, co-production can result in synergistic effects, where the presence of one enzyme enhances the production of others, creating a cascading effect that boosts overall productivity (Rathore and Singh, 2021; de Siqueira and Öner, 2023). By leveraging the

synergies between different enzymes, co-production aligns with the principles of green chemistry, emphasizing resource efficiency and reduced waste. Furthermore, the co-production of hydrolytic enzymes using gram waste as a substrate represents a promising frontier in enzyme biotechnology.

MATERIALS AND METHODS

Microorganism

Nesterenkonia sp. K-15-9-6, isolated from the Gulf of Khambhat, Gujarat, India was previously identified by molecular approaches. The strain was previously studied for hydrolytic enzyme production, dye degradation, and production of plant growth-promoting substances. This isolate was identified based on 16S rRNA sequence and submitted to NCBI Gene bank with the accession number ON331909. The bacterium was maintained on a modified nutrient agar medium (peptone 10 g/L, yeast extract 5 g/L, NaCl 25 g/L, agar 30 g/L, and pH 9.0) at 5 °C for further study.

Inoculum preparation

The K-15-9-6 culture from the slant was inoculated in sterile nutrient broth (pH 9.0) supplemented with 2.5% (w/v) NaCl and incubated at 37°C for 24 h. Growth was measured at 600nm and set the optical density of 1.0 which corresponded to 1.0% (v/v) inoculum. The prepared culture suspension was used as a 3.0% (v/v) inoculum for the experiment.

Co-production of hydrolytic enzymes

Submerged Fermentation (SmF) was carried out in 250 mL Erlenmeyer flasks containing 3 g of each dry solid agro-food waste separately. The flasks were autoclaved at 121 °C for 15 min and then, the corresponding amount of basal solution was inoculated with seed culture of 3% (v/v) and

was mixed with solid substrates. The basal solution contained 3% (w/v) gelatin, 2.5% (w/v) NaCl, and 1.0% (w/v) peptone. pH was adjusted to 9 by 20% Na_2CO_3 . The inoculated flasks were incubated at 37 °C for 120 h, on a 120 rpm rotary shaker. After the fermentation period, the broth was filtered using a muslin cloth, and the liquid fraction was collected manually and centrifuged for 10 min at 10,000 rpm. The pellets were discarded from the supernatants and used as crude enzymes for further analysis.

Quantitative assay for hydrolytic enzymes

The activity of xylanase, cellulase, and amylase was assayed by modifying the method of Bailey et al. (1992) by measuring the amount of reducing sugars liberated from the substrate using the DNS method (1959). Reaction mixture containing 3 mL of 0.5% birch wood xylan, 1% CMC, and 1% starch as substrate respectively for xylanase, cellulase, and amylase (prepared in 20 mM glycine-NaOH buffer, pH 9.0) and 1 mL of crude enzyme. The absorbance was measured at 540 nm in a spectrophotometer. One unit (U) of enzyme activity was defined as the amount of enzyme required to liberate 1 μmol of product (glucose/ xylose) released/min/mL (U/mL) under the assay conditions.

The lipase activity was estimated by modifying the method described by Maldonado et al (2012). The reaction mixture consisted of 19 mL of olive oil/Arabic gum emulsion (5% olive oil and 5% Arabic gum) in 100 mM potassium phosphate buffer, pH 7.0, and 1 mL of crude enzyme. One unit of lipase activity was defined as the amount of enzyme that liberates 1micromole of fatty acids equivalent per minute under the assay conditions.

Anson-Hagihara method (1958) was used to

analyze protease production with Hammerstein casein as a substrate. In this assay, the cell-free supernatant (0.5 ml) was incubated for 30 min at 37 °C with 3.0 ml of 0.6% (w/v) casein (prepared in 20 mM glycine-NaOH buffer pH 9.0). A UV-Vis spectrophotometer was calibrated to 280 nm to determine the tyrosine content present in the acid-soluble filtrate. Under specific test conditions, one unit of alkaline protease activity was defined as the quantity of enzyme that released 1 μg tyrosine $\text{ml}^{-1} \text{min}^{-1}$ from casein.

Optimization of the medium component: One variable at a time (OVAT)

Incubation period and pH

The production medium was inoculated with 3.0 mL of fresh culture suspension of *Nesterenkonia* sp. K-15-9-6 of optical density 1.0 at 660 nm and incubate them at 37°C for 120h. To check the production of hydrolytic enzymes 10mL of the sample was collected at every 24h of intervals and supernatant was collected after centrifugation at 10000 rpm for 10 min. The enzyme activity was measured as per the method mentioned above. Similarly, the effect of pH was analyzed by arranging the medium pH 7.0, 8.0, 9.0, 10.0, and 11.0. The pH was set after autoclave using a sterile 20% Na_2CO_3 solution. The supernatant was collected after centrifugation at 10000 rpm for 10 min and used as a crude enzyme to estimate the production of hydrolytic enzymes.

Gram waste concentration

The composition of the substrates and the process variables influence the enzyme synthesis in the shake flask method. Both are initially optimized by OVAT to explore the impact of different process parameters on the synthesis of amylase, xylanase, cellulase, lipase, and protease. The range in which they affect the process and gram waste

concentration was studied in the range of 2-10g%. This approach included altering a single parameter while keeping the other elements constant. Next, the set of experiments was incubated for 48h at 37°C and from the supernatant, all the hydrolytic enzyme production was measured using the above-mentioned procedure.

Inoculum volume and medium volume

The effect of inoculum volume and medium volume on the co-production of hydrolytic enzymes was estimated in the range of 3.0-15.0% v/v and 25-150 ml/250 ml flask, respectively. The optical density (1.0 at 660nm) of *Nesterenkonia* sp. K-15-9-6 was maintained and inoculated in different volumes in the production medium. Similarly, Medium volume (same composition of the nutrient) was varied in the production medium and incubated for 48h at 37°C. The supernatant was collected after centrifugation at 10000 rpm for 10 min and used as a crude enzyme to estimate the production of hydrolytic enzymes.

NaCl concentration

As the isolate is moderate halophilic in nature the NaCl concentration is optimized to increase their growth and enzyme production. The medium was prepared with different concentrations of NaCl (0-15.0g%). Next, the 3.0% v/v prepared K-15-9-6 suspension was used as inoculum for the experiment. After incubation at 37°C for 48h, the supernatant was collected and used as a crude enzyme to estimate the production of hydrolytic enzymes.

RESULTS AND DISCUSSION

Optimization of the medium component: One variable at a time (OVAT)

Incubation period and pH

The time course of K-15-9-6 was analyzed for up to 5 days for co-production of enzymes. The results indicate, that 48 h is the most appropriate incubation time that produced maximum hydrolytic enzymes in a single medium. However, over-incubation can reduce the synthesis of the enzymes. For example, cellulase (6.3 U/mL), amylase (5.08 U/mL) and lipase (3.76 U/mL) released maximally after 72 h of incubation, while protease (53.35 U/mL) and lipase (1.45 U/mL) produced in maximum amount after 48 h of incubation (Fig. 1). Further incubation up to 120h indicating drastic change in concentration of enzyme secretion. As the lower time with a minor difference in yield favours the formation economy, hence 48h incubation period is considered for further study. The pH variation on co-production of enzymes suggested, the K-15-9-6 produced maximum hydrolytic enzymes in alkaline pH range, while acidic, neutral, and extremely alkaline (pH >11.0) reduced the cumulative biosynthesis of enzymes (Fig. 2). The most favourable pH is pH 9.0 for co-production of protease (96.54 U/mL), lipase (1.5 U/mL) and xylanase (5.3 U/mL), while amylase (5.2 U/mL) and cellulase (3.5 U/mL) produced maximally at pH 8.0. There are several bacterial, actinomycetes and fungal species have been isolated by various researchers that grow and produce different hydrolytic enzymes in alkaline pH. Concerning time, bacteria require less time for the fermentation process compared to actinomycetes and fungi (Chugh *et al.*, 2016; David *et al.*, 2018; Rathore and Singh, 2021).

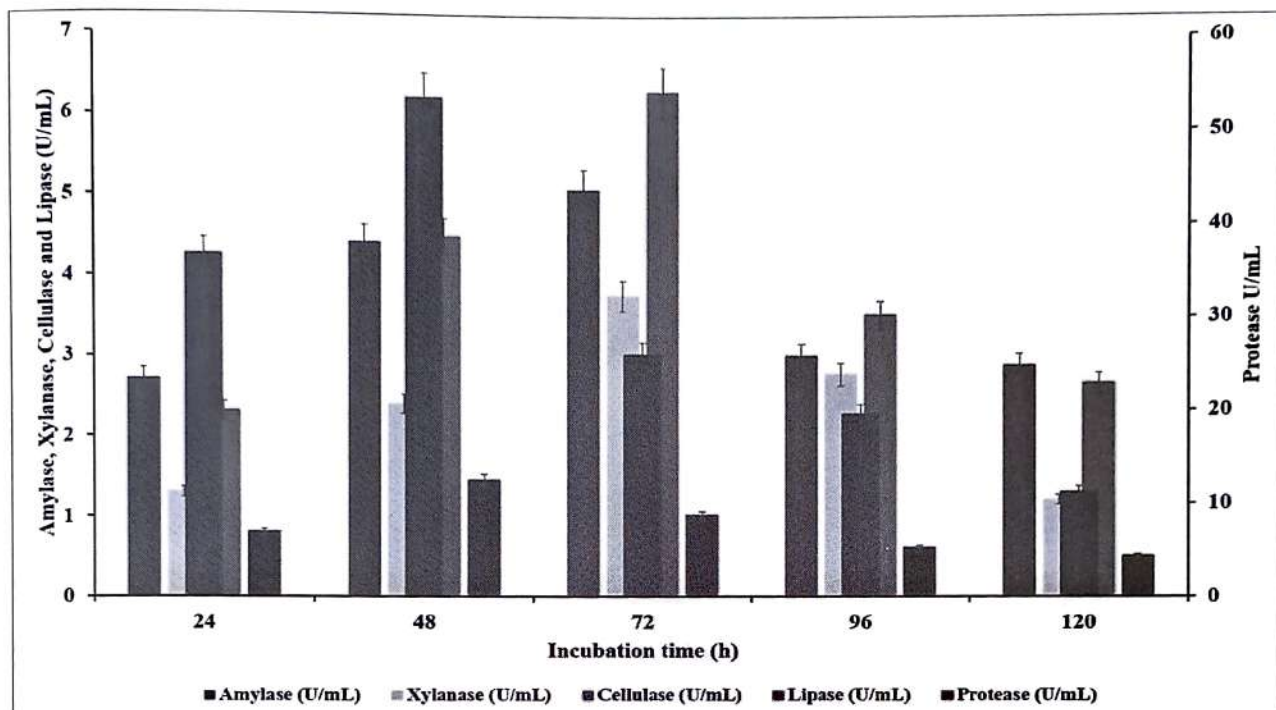


Fig. 1 Effect of incubation time on co-production of hydrolytic enzymes

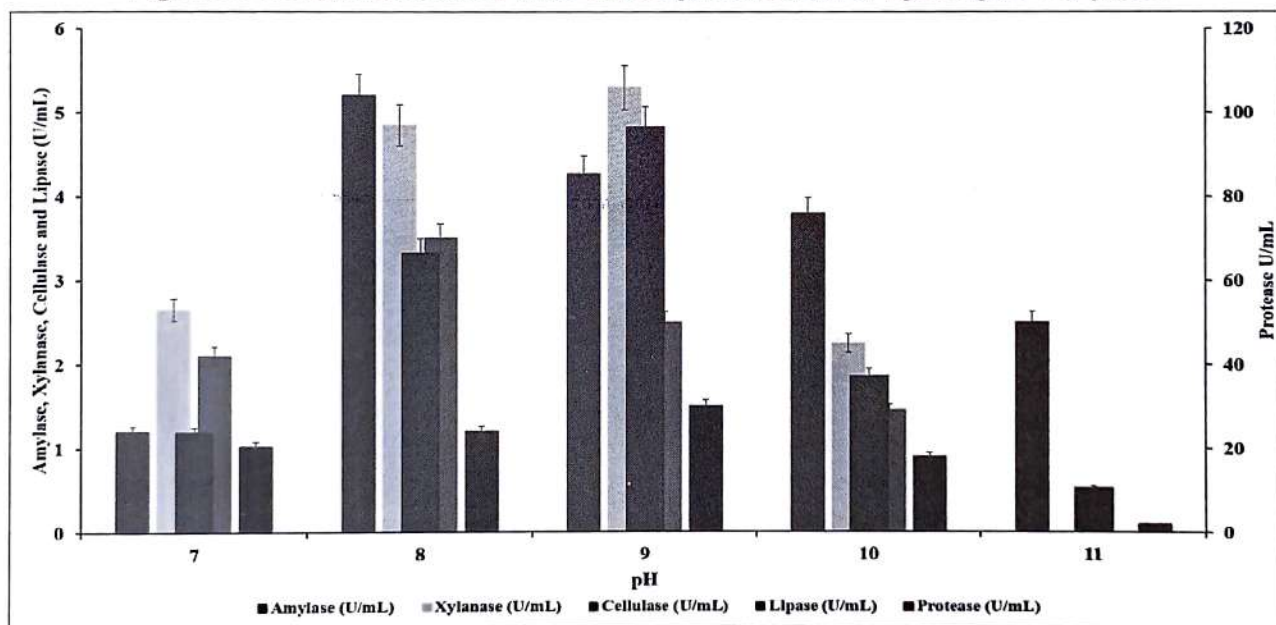


Fig. 2 Effect of pH on co-production of hydrolytic enzymes

Gram waste: Cost-effective substrate for the co-production of hydrolytic enzymes

Gram waste was tested for the co-production of hydrolytic enzymes. Experiment results indicate that gram waste supports the

simultaneous production of amylase, xylanase, protease, cellulase, and lipase. As the literature indicates the gram waste contains a high amount of protein, which enhanced the protease production up to a

maximum 111.5 U/mL at the concentration of 8.0w/v%. While the other hydrolytic enzyme production was observed in lower quantity.

The amylase produced 1.1U/mL, xylanase produced 3.9U/mL, cellulase produced 3.72U/mL, and lipase produced 1.45U/mL (Fig. 3).

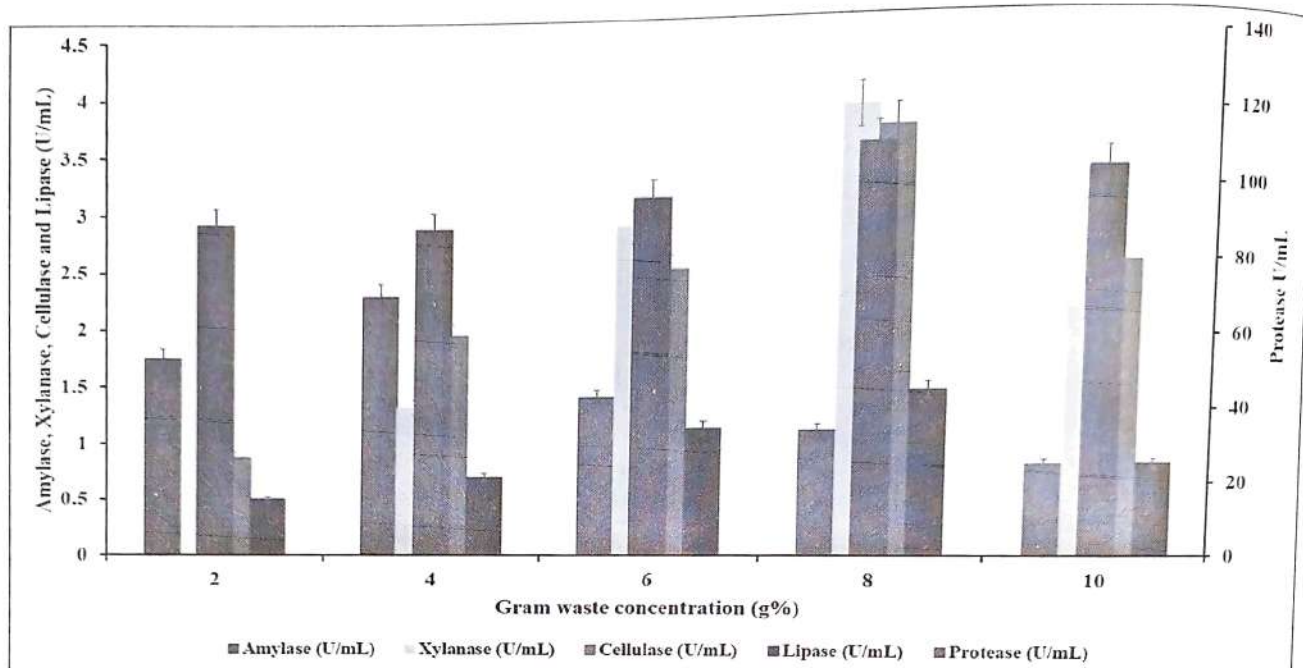


Fig. 3 Effect of Gram waste concentration on the co-production of hydrolytic enzymes

The synthesis of all enzymes is lowered by the decreasing content of gram waste. When compared to other waste sources, gram wastes are preferred as an economical and nutrient-rich raw material for the production of enzymes. Gram by-products, such as bran and husks, are a great substrate for bacterial fermentation because they have a unique composition of lipids, proteins, fibers, carbs, and bioactive substances (Prakasham *et al.*, 2006; Rodríguez Couto, 2008). The medium's nutritional richness is attributed to the high protein and carbohydrate content, which supply energy for microbial development. Due to its widespread cultivation, waste materials are produced in substantial and reliable quantities. The circular economy and trash reduction concepts are in line with the sustainable feature of using gram waste (Rodríguez

Couto, 2008; Suganthi *et al.*, 2011). Since the enzymes are useful in industrial processes like detergent, food processing, and biofuel generation, the composition of gram wastes facilitates their biosynthesis. These enzymes include protease, amylases, xylanases, lipases, and cellulases. Numerous scientists have employed agro-food wastes to co-produce enzymes. For example, potato peels (PP) (Tuysuz *et al.*, 2020), distillers dried grains with soluble/s (DDGS) (Chugh *et al.*, 2016; Cekmecelioglu and Demirci, 2020), feather meal, PP and rape seed cake (Bhange *et al.*, 2016), wheat bran (David *et al.*, 2018), and cottonseed oil and soybean meal (Niyonzima and More, 2014) and other natural organic waste such as DORB, PP, bagasse, cereal bran, husk, fruit peels & pomace, kitchen waste and sea-food wastes for the co-production of hydrolytic enzymes via fermentation (Arya *et al.*, 2022a).

Inoculum volume and medium volume

An inoculum volume was estimated in the range of 3.0-15.0%v/v, among them 5%v/v inoculum shows the highest co-production of enzymes. While higher inoculum (15.0%v/v) reduced the production of hydrolytic enzymes. Fig. 4 demonstrates, at 5.0%v/v inoculum maximum of 98.1U/mL of protease, cellulase 3.7U/mL, and xylanase 3.5U/mL, however, 3.0%v/v inoculum favours the amylase production (2.42U/mL). Also, Fig. 5 describes that 7.0%v/v inoculum enhanced the lipase production upto 1.7U/mL. This behaviour can lead to the phenomena like higher/lower cell density in limited nutrient quantity. At the same time, the volume of production medium is optimized. The results indicate that 75mL of medium volume is most

appropriate for higher production of protease (101.5U/mL), amylase (2.5U/mL), xylanase (3.69U/mL), and lipase (1.9U/mL), while, maximum cellulase (3.78U/mL) production is observed with 50mL production medium. During microbial fermentation, the inoculum volume and medium volume are crucial factors that can significantly influence the overall efficiency and productivity of the fermentation. It is essential for achieving maximum productivity, minimizing the risk of contamination, and ensuring efficient utilization of resources. These optimizations contribute to the economic feasibility and sustainability of enzyme production processes in the context of utilizing agro-food wastes (Kennedy and Krouse, 1999; Arya et al., 2021).

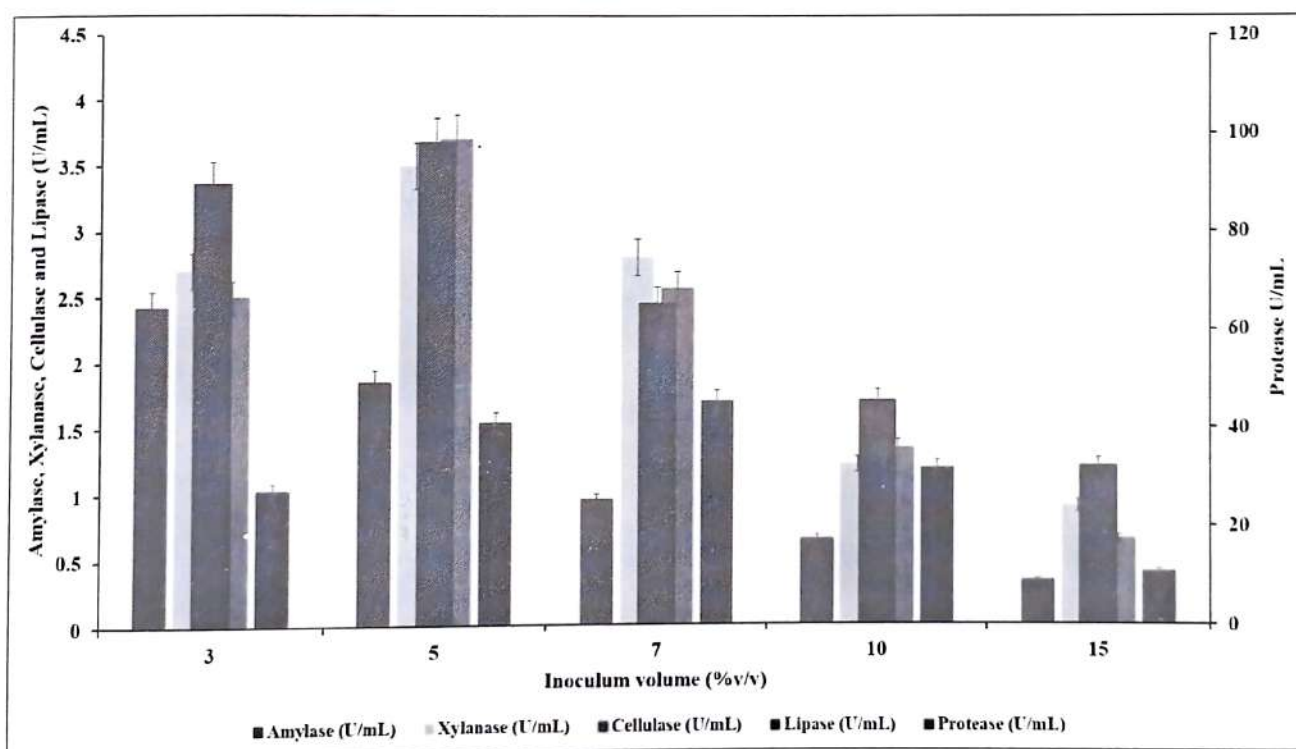


Fig. 4 Effect of inoculum volume on co-production of hydrolytic enzymes

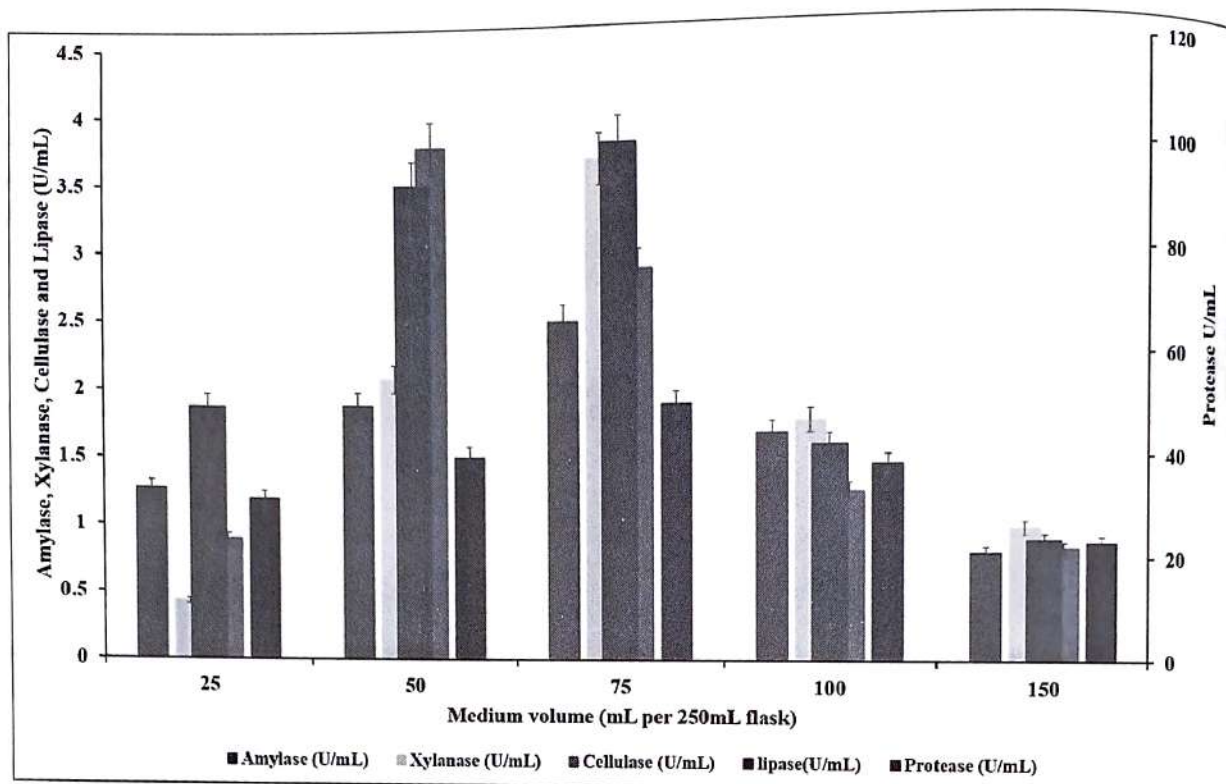


Fig. 5 Effect of medium volume on co-production of hydrolytic enzymes NaCl concentration

Furthermore, it has been documented that halophilic microorganisms may promote the synthesis of enzymes in an alkaline pH range of 8.5 to 11, in the presence of NaCl in the 0–15.0% (w/v) concentration range, as opposed to neutral and acidic conditions (Raval *et al.*, 2014). As the isolate is mordant halophiles, at 2.5w/v% NaCl concentration all enzymes are produced in maximum amount (Fig. 6). However, the growth and enzyme production was not observed without NaCl in the medium. Similarly, the higher concentration of NaCl is also not favour for the co-production of hydrolytic enzymes. During the fermentation, protease, amylase, xylanase, cellulase, and lipase are produced maximally up to 129, 5.89, 5.12, 5.66, and 4.99U/mL, respectively. Enzyme induction or suppression by certain compounds may be

influenced by environmental variables that affect the production of extracellular hydrolytic enzymes. The production of enzymes was affected by several factors, including pH, temperature, incubation period, aeration-agitation rate, and inoculum volume (Arya *et al.*, 2021; Arya *et al.*, 2022b). Most marine bacteria need an alkaline pH range and a mesophilic temperature range to produce enzymes; however, their production activity is reduced at very low and high pH, salt, and temperature ranges. It also depends on the source of the bacterial isolate. However, this extremophile releases a variety of enzymes that give it a unique capacity to function in such an environment (Dalmaso *et al.*, 2015).

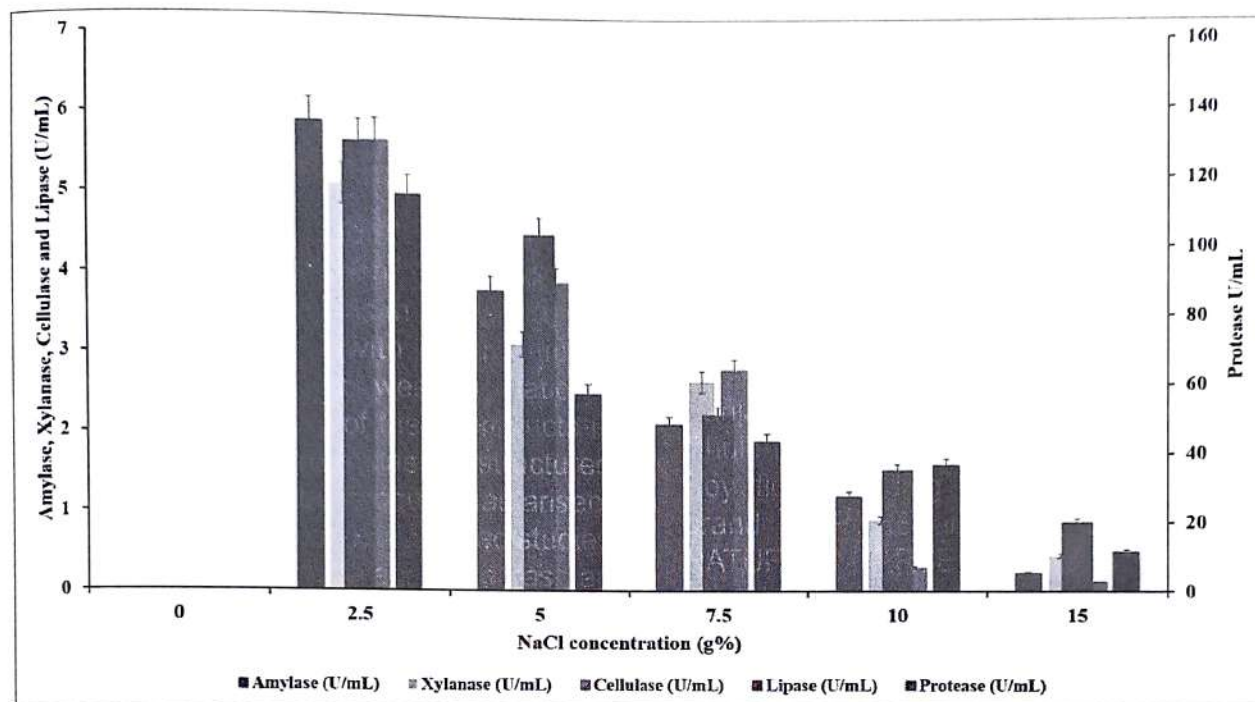


Fig. 6 Effect of NaCl concentration on co-production of hydrolytic enzymes

CONCLUSION

In conclusion, the global waste crisis spurred by population growth demands innovative approaches to sustainable waste management. Microbial enzyme synthesis offers a transformative solution. This study on *Nesterenkonia* sp. K-15-9-6 demonstrates simultaneous synthesis of various enzymes via submerged fermentation, utilizing cost-effective agro-food wastes, particularly gram waste, showcasing promising avenues for sustainable waste management. Co-production streamlines enzyme synthesis, enhancing efficiency and reducing costs. The optimal conditions-incubation time: 48h, pH: 9.0, gram waste: 8g%, inoculum volume: 5%v/v, medium volume: 75mL, NaCl concentration: 2.5%w/v-yield the maximum protease (129 U/mL), xylanase (5.12 U/mL), cellulase (5.66 U/mL), amylase (5.89 U/mL), and lipase (4.99 U/mL). This study underscores *Nesterenkonia* sp. K-15-9-6 potential for sustainable gram waste management and

enzyme co production. This study not only contributes to the understanding of enzyme production dynamics but also opens up promising avenues for the valorization of agro-food wastes, paving the way for sustainable and economically viable waste management strategies in the future.

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Field testing of multimedia CD on value-addition of mango for its comprehension by rural women

Manju*¹, Upadhyay R.² and Solanki D.³

Department of Home Science, University of Rajasthan, Jaipur
Department of EECM, College of Community & Applied Science, MPUAT, Udaipur
E-mail : manjuch059@gmail.com

ABSTRACT

Technology has reshaped communication and the integration of multimedia in communication has expanded its inclusivity and outreach. The role of technology in agriculture is transformative, offering farmers new possibilities. This study aimed on standardization of a multimedia CD to empower rural women on value-addition of mango. The development of multimedia CD was done in two phase such as designing of multimedia CD and field testing of multimedia. The designed multimedia CD was field tested with 30 rural women of village Dussehra in Banswara panchayat samiti of Banswara district, Rajasthan. Overall comprehension of the multimedia CD was found excellent with MPS 92.22. The multimedia CD emerges as a powerful tool to uplift the lives of rural women, encouraging entrepreneurship and the overall development of rural communities.

Keywords: Value-addition, Multimedia CD, Digital Resource, Empowerment, Field Testing, Comprehension, Measuring understanding, Rural Women

INTRODUCTION

In the ever-evolving landscape of communication, technology plays a pivotal role in shaping the way people access and engage with various media channels. The rapid advancements in technology have not only revolutionized the modes of communication but have also transformed the entire media ecosystem. From traditional print media to the vast realm of digital platforms, technology has significantly impacted the accessibility, reach, and dynamics of communication media. The advent of the internet marked a paradigm shift in the way people access information and communicate. Digitalization has made communication instantaneous, breaking down geographical barriers and enabling real-time interaction. Social media platforms,

online news portals, and messaging apps have become integral parts of daily life, providing a diverse range of communication options.

The integration of text, images, audio, and video has enhanced the richness and effectiveness of communication. Platforms like YouTube, Instagram, and Twitter exemplify the growing preference for multimedia content, enabling users to express themselves in diverse and engaging ways. Technology has played a crucial role in making communication media more accessible and inclusive. Mobile devices, smartphones, and high-speed internet have ensured that people from various socio-economic backgrounds can access information and communicate seamlessly. Social media activism, online communities, and digital platforms have given a voice to

marginalized groups, fostering a more inclusive media landscape.

Technology's influence on communication channels in agriculture is undeniable, offering farmers unprecedented opportunities to improve productivity, sustainability, and connectivity. From precision farming and mobile technology to social media platforms and e-marketplaces, the digital transformation of agriculture is creating a more interconnected and informed farming community.

Agriculture, the backbone of economies worldwide, faces numerous challenges, including climate change, market fluctuations, and resource constraints. Enhancing the resilience and sustainability of agriculture is imperative to ensure food security and the livelihoods of millions. One powerful strategy is the promotion of value-addition in agricultural produce, which not only augments farmers income but also contributes to building a robust and sustainable agricultural ecosystem.

Value-addition encourages farmers to diversify their agricultural products, reducing dependence on a single crop. By processing raw produce into value-added goods such as jams, juices or packaged snacks, farmers can mitigate the impact of market fluctuations and climate-related risks. Value-addition opens new avenues for farmers to access broader markets. Processed and value-added products often have a longer shelf life, enabling farmers to reach distant markets and cater to consumer demands for convenience. This expanded market access not only increases profitability for farmers but also reduces the vulnerability associated with localized market disruptions. Value-addition often involves adopting sustainable practices. For instance, converting surplus fruits into dehydrated snacks or creating

organic fertilizers from agricultural residues aligns with environmental sustainability. By optimizing resources and reducing waste, value-addition contributes to a more efficient and ecologically friendly agricultural system, promoting long-term sustainability. Value-addition can play a pivotal role in rural development by fostering local entrepreneurship and employment. Establishing small-scale processing units or cooperatives empowers local communities, providing them with the skills and resources to add value to their agricultural produce. Women play a pivotal role in various stages of farming, from sowing and nurturing crops to harvesting. However, they often lack access to recent technologies hindering their contribution and empowerment. Providing women with training on value-addition of agricultural produce has the potential to bring about prosperity in agriculture sector and empower these women economically.

Therefore, a study was planned to standardise the multimedia CD on value-addition of mango for rural women. This multimedia CD will work as digital resource for rural women who can access it any-time anywhere. This multimedia CD can also be used by extension functionaries like Home Scientists, Krishi Vigyan Kendra (KVKs), and other agriculture and rural development departments as a communication material in training rural women on value-addition of mango.

Review of literature

Sasikala *et al.*, (2012) studied the effect of multimedia CD on knowledge of pig farmers and concluded that the multimedia CD had a significant impact on scientific pig farming practices.

Sasikala and Tiwari (2014) reported the effectiveness of the Multimedia Training Module (MTM) on Integrated Farming

Systems (IFS) in enhancing farmers knowledge and skills in Tamil Nadu. The MTM was well-received by farmers, who found it useful and relevant, aiding their understanding of IFS concepts and benefits. The study revealed a preference for the MTM over traditional extension methods like field demonstrations and lectures. Notably, 68.75% of respondents found the multimedia CD highly effective in arousing curiosity and interest. Additionally, 85.62% perceived the multimedia CD as very useful, with 14.37% finding it useful.

Yadav and Verma (2014) standardized a multimedia CD on fruits and vegetables processing and preservation for rural women and reported that the multimedia CD positively impacted the knowledge and skill of rural women and there was 63.51 per cent gain in knowledge and attitude of women regarding fruits and vegetable processing.

Sharma *et al.*, (2012) reported in a study titled "Effectiveness of a CD-ROM for knowledge gain about abortion in dairy animals" that there was 71.11 per cent gain in the knowledge of the farmers after exposure to the CD-ROM regarding all aspects of abortions in dairy animals.

Lohmann and Frederiksen (2018) emphasized the significance of information technology, integrated with multimedia audio/video in making teaching effective. It will also be a vital tool for teachers and students to add information technology into curricula, material and instructions.

Findings of a study conducted by Gautam *et al* (2019) in Nadia and North 24 districts of West Bengal indicate the significant role of modern media tools in the adoption of clean milk production practices among dairy farmers. The findings revealed that the majority of dairy farmers (67.50%) cleaned their animal sheds daily, and a significant

proportion (44.17%) followed pre-milk teat washing with water to remove dirt and dung. Additionally, 26.66% of the respondents practiced full-hand milking and washed their hands with soap before milking, while 23.33% of farmers used a sieve during milk transfer.

Lalitha and Rani (2020) conducted a study to analyze the content effectiveness of a multimedia module on domestic water sanitation and highlighted the importance of diverse communication strategies that provide practical utility, informative, and adequacy in imparting education to clients with low socio-economic backgrounds.

MATERIAL AND METHODS

The process of development of multimedia CD can be divided into two phases: designing of multimedia CD and field testing of multimedia CD.

1. Designing of multimedia CD on value-addition of mango

Designing of multimedia CD had two components i.e. preparation of multimedia CD and expert evaluation of multimedia CD

i. Preparation of multimedia CD

A video script was written using scientific information available on the value-addition of mango drawing insights from both primary and secondary resources. The script was classified into different chapters i.e., introduction, preparation of values added products of mango like *Amchoor*, raw mango *murabba*, mango pickle, raw mango squash, mango jam, *Aam-papad* and preservation of mango as pulp and closure. A separate template of case study of a successful women entrepreneur was added to the script. Following the written script, essential

video scenes, photographs and illustrations were initially captured and then assembled according to the storyboard. The editing and synchronization of audio and video of the multimedia CD was done using Pinnacle Studio version 9 video editing software. The storyboard presented the visual description of long, medium and close-up shots. The audio editing software used for the voice over was Sound Forge version 8.0. The assembled video clippings were edited and incorporated with voice over audio, background music and sound effects. An introductory slide having title of the multimedia CD and author description was also added in the starting and a closing slide were also added to the multimedia CD

ii. Expert evaluation of multimedia CD

The developed video CD was then evaluated by a panel of experts from the Department of Extension Education and Communication Management, and Foods and Nutrition. An evaluation sheet was prepared by the researcher which included visual and audio aspects of evaluation. The visual evaluation aspect had 10 evaluation criteria i.e., purpose accomplished, content coverage, logical sequence, organization/layout, illustration, visual clarity, attention-catching, self-explanatory, synchronization of audio and video, and overall presentation. The audio evaluation aspect included 5 evaluation criteria such as content clarity, voice, pace and speed of narration, background music and overall presentation. Experts evaluated the multimedia CD on a 5-point continuum i.e., excellent, very good, good, fair and poor scoring 5,4,3,2 and 1 respectively. Suggestions given by the experts were

incorporated, scores were compiled in MS Excel and Mean Weighted Scores (MWS) were calculated. The whole process of designing the video CD spanned over five months, with initial four months dedicated to preparation of the video script, video editing and disc authoring and the remaining one month for expert evaluation of video CD.

2. Field testing of multimedia CD on value-addition of mango

The designed multimedia CD was field tested with 30 rural women in the age group of 25-30 years, who were willing to participate in the study. The sample was selected randomly from a list of women prepared in the village Dussehara in Banswara panchayat samiti of Banswara district, Rajasthan. Banswara district was selected purposively for the study as it the highest mango producing district of Rajasthan and it is one of the districts which comes under extension services of Maharana Pratap University of Agriculture and Technology (MPUAT), Udaipur.

Data were collected through personal interview method. A personal interview schedule was prepared by the researcher. The interview schedule had two sections. First section of the interview schedule mainly comprised the personal attributes of the respondents such as age, marital status, education, occupation, caste, organisational membership, family type and size, family occupation, land holding, household type, livestock ownership and dwelling for livestock and media ownership. For this purpose, Socio-Economic Status (SES) scale developed by Gupta (2000) was slightly modified and used. The second section of the interview schedule

was an open-ended tool having questions related to different aspects of value-addition of mango. Data were analysed and interpreted statistically using frequency, percentage and Mean Per cent Score (MPS).

RESULTS AND DISCUSSION

Comprehension of the multimedia CD was recorded while standardizing the multimedia CD. Data collected were analysed using different statistical tools and interpretation of the data is presented here in this section.

1) Socio-economic status of the respondents

The statistics in Table 1 provide the information that most of the respondents (80%) had low socio-economic status while 20 per cent respondents were into medium socio-economic status. None of the respondents were found to be in high socio-economic status.

Table 1 : Socio-economic status of the respondents

S. No.	Socio-economic status	f	%
1.	Low	24	80
2.	Medium	06	20
3.	High	00	00

2) Comprehension of multimedia CD

Comprehension of the multimedia CD was analysed as component wise and overall comprehension of multimedia CD. The multimedia CD introduced the concept value-addition-need and benefits followed by method of preparation of selected value-added products of mango i.e. mango jam, Aam-

papad, Amchoor, mango pickle, raw mango *murabba*, raw mango squash and preservation of mango as pulp.

i. Component wise comprehension of multimedia

Table 2 presents the description of messages comprehended in each component of the multimedia CD on value-addition of mango. In the component "Value-addition-need and benefits", 90 per cent respondents understood all the messages. Further, comprehension of "Amchoor" and "mango pickle" was 100 per cent. It can also be interpreted from the table that 96.67 per cent respondents were able to comprehend the messages of plate test for making mango jam and process of making raw mango squash. However, comprehension of messages in the subcomponent "raw mango *murabba*" was comparatively low as 86.67 per cent respondents could comprehend the messages.

The possible reason for 100 percent comprehension of Amchoor and mango pickle is that these two products are traditionally prepared in community and women could relate it to their real-life situations. In a discussion with the respondents, researcher found that women did not even hear about many of the mango products and they had no idea that products like mango jam, Aam-papad or preservation of mango pulp can also be prepared from mango. The introductory part of the multimedia CD covering concept of value-addition, its need and benefits was more conceptual in nature, this was the reason that it was comparatively comprehended by a smaller number of respondents.

Table 2 : Comprehension of messages in different components of multimedia CD n=30

S. No.	Component	f	%
1.	Value-addition- need and benefits	27	90.00
2.	Value-added mango products		
a.	Mango jam		
i	Ingredients for preparing mango jam	27	90.00
ii	Process of preparing mango jam	26	86.67
iii	Plate test	29	96.67
b.	<i>Aam-papad</i>		
i	Ingredients for preparing <i>Aam-papad</i>	27	90.00
ii	Process of preparing <i>Aam-papad</i>	27	90.00
c.	Preservation of mango as pulp		
i	Ingredients for preserving mango as pulp	27	90.00
ii	Process of preserving mango as pulp	27	90.00
d.	<i>Amchoor</i>	30	100.00
e.	Mango pickle		
i	Ingredients for preparing mango pickle	30	100.00
ii	Process of preparing mango pickle	30	100.00
f.	Raw mango <i>murabba</i>		
i	Ingredients for preparing raw mango <i>murabba</i>	26	86.67
ii	Process of preparing raw mango <i>murabba</i>	26	86.67
g.	Raw mango squash		
i	Ingredients for preparing raw mango squash	26	86.67
ii	Process of preparing raw mango squash	29	96.67

Similar findings were reported by Sasikala and Tiwari (2014) that 85.62 percent farmers found the multimedia CD very useful and 14.37 percent respondents found it useful while none of the farmers found the multimedia CD to be not useful.

Overall comprehension of multimedia CD
Table3 presents the information about overall

comprehension of the multimedia CD that was measured by calculating Mean Percent Scores (MPS). The overall presentation of the multimedia CD was comprehended very good with the Mean Percent Score (MPS) of 92.22 that means the CD was very easy to comprehend by the respondents.

Table 3 : Overall comprehension of messages through multimedia CD n=30

S. No.	Component	Mean Percent Score (MPS)
1.	Value-addition - need and benefits	90.00
2.	Mango products	92.38
3.	overall presentation	92.22

The comprehension of other components of multimedia CD was also very good as the MPS scores for both "Value-addition- need and benefits" and "Mango products" were 90 and 92.38 respectively. Finding are in confirmation with Bala et al (2019) who reported very good overall comprehension of messages through multimedia with MPS 93.62.

On the basis of findings it could be concluded that the comprehension of multimedia CD was excellent. It also confirms that the multimedia CD was meticulously designed and thoughtfully organised. The CD's content was not only pertinent to its target audience but also delivered in a manner that captivates and involves the intended users. This can be used as a standardised communication material by different extension functionaries for capacity building of rural women on value-addition of mango.

CONCLUSION

The findings presented here emphasize the potential of multimedia technology as a catalyst for knowledge dissemination and skill enhancement in agricultural practices. Through this study, an easily accessible and interactive learning tool tailored to the unique needs of rural women has been developed. This multimedia CD on value-addition of mango will serve as a comprehensive digital resource that will not only equip the rural women with necessary knowledge and skills but also facilitates economic independence and entrepreneurship.

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Production performance of major cereals in Rajasthan

A.V. Mhaskey^{1*}, G. L. Meena², L. Sharma³, B. Upadhyay⁴, L. N. Mahawer⁵ and D. Jain⁶

Rajasthan College of Agriculture, MPUAT, Udaipur, Rajasthan

*Email : akashmhaskey@gmail.com

ABSTRACT

The study conducted an in-depth analysis of the agricultural trends in Rajasthan, India, focusing on wheat and bajra (pearl millet) production from 2000-01 to 2021-22. Using secondary data from diverse sources, including Rajasthan Agricultural Statistics and the Ministry of Agriculture and Farmers Welfare, the study employed various analytical methods to assess growth, variability, trend, and decomposition analysis of these major cereal crops. For wheat, the compound annual growth rate (CAGR) analysis revealed significant growing area and output during Period-I (2000-01 to 2010-11), followed by non-significant growth in Period-II (2011-12 to 2021-22), with a note worthy surge in productivity during both periods. Similarly, bajra cultivation exhibited substantial expansion in area and output in Period-I, followed by a decline in area but maintenance of production growth in Period-II. Both crops showed greater instability in production compared to area and yield, with bajra experiencing slightly higher instability. Trend analysis indicated quadratic model for wheat area and production, exponential for bajra production, and linear for both crops' yield. Decomposition analysis revealed that while yield contributed significantly to wheat production growth across all periods, bajra production growth was primarily driven by yield during Period-I but suffered from declining yield and negative area effects overall. These findings offer beneficial insights into the agricultural dynamics of Rajasthan, emphasizing the need for targeted interventions to sustainably enhance cereal crop production amidst changing environmental and socio-economic conditions.

Keywords : Wheat, Bajra, Compound annual growth rate, Variability analysis, Trend analysis, Decomposition analysis.

INTRODUCTION

In India, agriculture remains a crucial driver of socio-economic progress, with most of the population relying on this sector. It holds particular significance for the disadvantaged segments of Indian society, such as those with low incomes and vulnerable conditions. The development of other sectors in India is intricately connected to agricultural

production, benefiting from both backward and forward linkages. During the period spanning from 2012-13 to 2018-19, there was a remarkable 59% increase in the monthly income per agricultural household in India, rising from ₹ 6426 to ₹ 10218. This significant growth can be attributed primarily to the implementation of various initiatives aimed at supporting farmers, such as the PM-KISAN Scheme introduced in 2018, the Pradhan Mantri Fasal Bima Yojana initiated

in 2016, the Pradhan Mantri Krishi Sinchai Yojana launched in 2015, and the e-NAM initiative established in 2016. These programs have played a pivotal role in boosting agricultural incomes and uplifting the farming community. The liberalization of markets throughout the country also holds immense importance in ensuring that farmers receive fair prices for their agricultural products. These noteworthy measures have made substantial contributions to the progress, empowerment, and stability of farmers (Anonymous, 2019).

Rajasthan currently holds the distinction of being the biggest state in India, encompassing an expansive area of 34.22 million hectares, which corresponds to 10.41 percent of the India's total geographic region area. The economy of Rajasthan heavily relies on the agriculture and allied sectors, which acts as a pivotal contributor to the Gross State Domestic Product (GSDP). The Gross State Value Added (GSVA) has exhibited a significant growth, with a noticeable increase from 1.569 lakh crores in 2018-19 to 2.089 lakh crores in 2022-23, showcasing a growth of 7.5 percent at constant prices of 2011-12. When considering current prices, the GSVA of the Agriculture and associated sectors experienced a substantial surge from ₹ 2.22 lakh crore in 2018-19 to ₹ 3.79 lakh crore in 2022-23, demonstrating a CAGR of 14.33 percent (Rajasthan Agriculture Department, Government of Rajasthan, 2023).

In the year 2022-23, the state achieved a total food grain production of 253.99 lakh tonnes. Among these, *kharif* production contributed 97.98 lakh tonnes, while *rabi* food grain production accounted for 156.02 lakh tonnes. In terms of cereals, *kharif* cereals production reached 77.84 lakh tonnes, while *rabi* cereals production amounted to 128.73 lakh tonnes. (Rajasthan Agriculture Department,

Government of Rajasthan, 2023). Among the cereal group, bajra covers 47.02% of the total area and contributes to 28.85% of the production. On the other hand, wheat occupies 30.52% of the area and accounts for 50.21% of the production.

The examination of the growth, variability, trend and decomposition of major agricultural commodities holds significant importance in formulating effective agricultural policies. Rajasthan, being the largest state in India renowned for its rich food and cultural heritage, stresses the importance of examining the growth rate, variation, trend and decomposition of its major crops.

Ensuring sustainable agricultural performance requires both high growth and low instability in production. There has been growing concern that technological advancements in cereal production have led to increased variability, which is seen as a significant factor impacting agricultural stability. In the state of Rajasthan, wheat and bajra are the major cereal crops with the highest area and production. Given the significant implications for policymakers, it is crucial to assess the extent of growth, instability, trend and decomposition analysis in cereals production.

MATERIALS AND METHODS

The investigation utilized secondary data from multiple sources such as Rajasthan Agricultural Statistics at a Glance, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India, and Indiatat.com. The data covered a period of 22 years, from 2000-01 to 2021-22, and included figures on the area, production, and yield of wheat and bajra. This data was then analyzed to assess the growth, variability, trend, and decomposition analysis.

1. Analysis of compound annual growth rate

The Compound Annual Growth Rate (CAGR) was computed for the area, production, and yield of major cereals within Rajasthan. This calculation spanned a 22-year period from 2000-01 to 2021-22. The data was then segmented in two distinct sub-periods: Period-I (2000-01 to 2010-11) and Period-II (2011-12 to 2021-22). An exponential function of the form described below was utilized for this analytical process.

$$Y = a b^t e^{U_t} \quad (1)$$

Where,

Y = Area / Production / Yield

a = Intercept

b = Regression coefficient (' a ' and ' b ' are the parameters to be estimated)

U_t = Disturbance term in year ' t '

Equation (1) was converted into a log-linear format and expressed as follows:

$$\log Y = \log a + t \log b + U_t + \log e \quad (2)$$

Equation (2) was estimated using the Ordinary Least Squares (OLS) technique.

The compound growth rate (g) was subsequently computed as follows:

$$g = (b - 1)100 \quad (3)$$

Where,

g : Compound growth rate in (%) per annum

b : Antilog of $\log b$

The standard error of the growth rate was estimated and tested for significance using the ' t ' statistic. The formula used for the ' t ' statistic is as follows:

$$t = \frac{\bar{x} - \mu}{s / \sqrt{n}}$$

n = sample size

$\bar{x}$ = mean

s = standard deviation

μ = population with mean and unknown standard deviation

2. Instability analysis

Instability was assessed employing the Cuddy-Della-Valle Index. While the Coefficient of Variation (CV) is a straightforward measure of instability, it does not fully capture the instability existing in time series data due to the presence of trend components. To address this limitation, a formula proposed by Cuddy and Della (1978) was employed to overcome the issue of trend component interference. The instability index, as proposed by Cuddy and Della Valle in 1978, is calculated using the following expression:

$$CDVI = CV (1 - R^2)^{0.5}$$

CV = Coefficient of variation (in per cent)

R^2 = The coefficient of determination

3. Trend analysis

To analyze the trends in the area, production, and yield of major cereals, various models were utilized, encompassing linear, quadratic, cubic, exponential, and other relevant models. The following models were subsequently used to evaluate the trends in area, production, and yield:

A) For Linear trend

$$X_t = a + b_t$$

Where,

X_t = Area/production/yield in year ' t '.

t = time element which takes the value 1,2,...n.

a = intercept

b_t = regression coefficient

B) For Exponential trend

$$X_t = ab^t$$

$$\log X_t = \log a + t \log b$$

Where,

X_t = Area/production/yield of commodity in year 't'.

t = time element which takes the value 1,2,...n.

$\log a$ = intercept

$\log b$ = regression coefficient

C) For Quadratic trend

$$X_t = ax^2 + bx + c$$

Where,

X_t = Area/production/yield of commodity in year 't'.

t = time element which takes the value 1,2,...n.

a = coefficient of determination

b = x-intercept

c = y-intercept

D) For cubic trend

$$X_t = ax^3 + bx^2 + cx + d$$

Where,

X_t = Area/production/yield of commodity in year 't'.

t = time element which takes the value 1,2,...n.

$a, b, c,$ and d represent the parameters to be estimated.

The optimal trend model was chosen based on the highest R-squared value and the significance of its variables.

4. Decomposition analysis:

To investigate the decomposition of sources of output growth for selected crops spanning a 22-year period from

2000-01 to 2021-22, an analysis was conducted. The data was additionally divided into two sub-periods: Period-I (2000-01 to 2010-11) and Period-II (2011-12 to 2021-22).

The sources of production growth were examined using the decomposition model proposed by Minhas & Vaidyanathan (1965).

The relative contributions of area, yield, and their interaction effect to the total output change in Wheat and Bajra was calculated. In this methodology, A_0 , P_0 , and Y_0 represent the area, production, and yield in the base year, while A_n , P_n , and Y_n denote the corresponding values in the n^{th} year.

$$P_0 = A_0 \times Y_0$$

$$P_n = A_n \times Y_n$$

Where,

A_0 and A_n represent the area, and Y_0 and Y_n represent the yield in the base year and n^{th} year, respectively.

$$P_n - P_0 = \Delta P$$

$$A_n - A_0 = \Delta A$$

$$Y_n - Y_0 = \Delta Y \quad (2)$$

From equation (1) and (2) we can write

$$P_0 + \Delta P = (A_0 + \Delta A)(Y_0 + \Delta Y)$$

Hence,

$$P = \frac{A_0 \Delta Y \times 100}{\Delta P} + \frac{Y_0 \Delta A \times 100}{\Delta P} + \frac{Y_0 \Delta A \times 100}{\Delta P}$$

Production = Yield effect + Area effect + Interaction effect

Where,

P = Change in production

ΔA = Change in area ($A_n - A_0$)

ΔY = Change in yield ($Y_n - Y_0$)

Therefore, the total change in production was decomposed into three

components: the yield effect, the area effect, and the interaction effect resulting from changes in both yield and area.

RESULTS AND DISCUSSION

Estimation of growth rate in area, production and yield of major cereals in Rajasthan

In the current research, the Compound Annual Growth Rate (CAGR) of area, production, and yield of major cereals in Rajasthan was calculated for the period spanning from 2000-1 to 2021-22. This 22-year period was further subdivided into three sub-periods: Period-I (2000-01 to 2010-11), Period-II (2011-12 to 2021-22), and Overall Period (2000-01 to 2021-22). The growth rate in each period, in terms of area, production, and yield of major cereals, is presented in the tables. The significance of the growth rate was assessed using the student's t-test.

1. Compound Growth rate in Area, Production and Yield of Wheat

Table 1 presents the Compound Annual Growth Rate (CAGR) of wheat in

Rajasthan during Period-I, Period-II, and the Overall Period. In Period-I (2000-01-2010-11), wheat exhibited significant growth in both area and production, and a non-significant growth in yield. Specifically, the area of wheat in Rajasthan experienced a significant growth of 3.88%, while production showed a growth of 6.35%. However, the yield recorded a non-significant growth of 2.38%. This finding is consistent with the research carried out by Udhayan *et al.* (2023), who also stated positive and significant growth in wheat during the period 2001-02 to 2010-11.

In Period-II (2011-12 to 2021-22), wheat exhibited negatively non-significant growth rates in area (-1.09%), while production (0.72%) recorded positive and non-significant growth rates. Notably, a positive and significant growth in yield (1.83%) was recorded during this period. During the Overall Period (2000-01 to 2021-22), wheat in Rajasthan showed a significant growth in area (2.27%), while production (4.20%) and yield (1.89%) exhibited non-significant growth rates.

Table 1: Compound Growth Rates in Area, Production and Yield of Wheat

Particulars	(In Per cent)		
	Period-I (2001-2011)	Period-II (2012-2022)	Overall Period (2001-2022)
Area	3.88***	-1.09 ^{NS}	2.27***
Production	6.35**	0.72 ^{NS}	4.20 ^{NS}
Yield	2.38 ^{NS}	1.83**	1.89 ^{NS}

Note:*** Significant at 1 per cent level of significance, ** Significant at 5 per cent level of significance, * at 10 per cent level of significance and ^{NS} Non-significant

2. Compound Growth rate in Area, Production and Yield of Bajra

Table 4.2 outlines the CAGR for bajra cultivation in Rajasthan, encompassing area, production and yield during distinct periods. During Period-I, Bajra cultivation demonstrated significant growth in area and production, with a CAGR of 1.91% and 5.61% respectively, both significant at the 5% level. These findings indicated a substantial expansion in both the cultivated area for Bajra and the overall production output. Moreover, the yield also exhibited significant growth, with a CAGR of 3.69%, highlighting efforts to improve yield per unit of land during this period.

In contrast to Period-I, Period-II (2011-12 to 2021-22) witnessed a contrasting trend in Bajra cultivation. The CAGR for area showed a negative growth rate of -1.03%, significant at the 5% level, suggesting a slight decline in the cultivated area for Bajra during this period. Production maintained a growth rate of 0.02%, albeit non-significant, indicating a marginal increase in Bajra output. Notably, the yield experienced a significant and growth rate of 1.05%,

emphasizing continued efforts to enhance yield per unit of land despite challenges in maintaining the cultivated area.

Across the overall period (2000-01 to 2021-22), Bajra cultivation witnessed mixed trends in growth rates. The CAGR for area showed a significant negative growth rate of -0.88%, indicating a slight overall decline in the cultivated area for Bajra. However, production maintained a growth rate of 2.74%, significant at the 1% level, suggesting an overall increase in Bajra output. The yield also exhibited significant growth, with a CAGR of 3.62%, emphasizing sustained efforts to improve yield per unit of land throughout the period.

These findings emphasize the complex dynamics influencing Bajra cultivation, including efforts to balance expansion in cultivated area with improvements in yield to ensure sustainable production growth. Further research focusing on factors influencing acreage growth and yield enhancement in Bajra cultivation could provide valuable insights for enhancing productivity and sustainability in Bajra production systems.

Table 2 : Compound Growth Rates in Area, Production and Yield of Bajra

Particulars	(In Per cent)		
	Period-I (2001-2011)	Period-II (2012-2022)	Overall Period (2001-2022)
Area	1.91**	-1.03**	-0.88**
Production	5.61**	0.02**	2.74**
Yield	3.69**	1.05**	3.62**

Note: *** Significant at 1 per cent level of significance, ** Significant at 5 per cent level of significance, * at 10 per cent level of significance and ^{NS} Non-significant

Estimation of Instability in the Area, Production and Yield of Major Agricultural Commodities in Rajasthan

This section examined the variations observed in the area, production, and yield of wheat and bajra crops specifically in Rajasthan. To reapunderstanding of the extent of instability, it's important to consider measures of instability rather than just focusing on the direction of increase or decrease in the cereal crops' area, production, and yield.

The time frame of the study, spanning from 2000-01 to 2021-22, was partitioned into three sub-periods: Period-I (2000-01 to 2010-11), Period-II (2011-12 to 2021-2022), and Overall-Period (2000-01 to 2021-22). In terms of the instability index, values exceeding 30 are classified as high instability, while values below 30 are regarded as low instability.

1. Instability in area, production and yield of wheat crop in Rajasthan

(i) Area:

Table 3 provides insights into the instability of wheat crop area. During Period-I, the state exhibited lower variation based on the Cuddy-Della-Valle index (CDVI), the instability in Period-I was 9.62%. Similar observations were noted for Period-II

and the Overall Period in the state. In Period-II, the instability was 6.89% while for the Overall Period, CDVI showed 13.70% instability.

(ii) Production:

Like the area, the production of wheat displayed a comparable pattern. During Period-I, wheat production exhibited less variation according to the Cuddy-Della-Valle index (CDVI) at 12.73%. This trend persisted in Period-II and the Overall Period in the state. In Period-II, the instability was 9.98% while for the Overall Period, CDVI indicated 24.62% instability.

(iii) Yield:

During Period-I, the yield of the wheat crop exhibited less variation with instability of 4.66%. A similar pattern was noticed in Period-II and the Overall Period. In Period-II, the instability was 6.13% while in the Overall Period, CDVI indicated 12.08% instability.

The instability in the area, production, and yield of wheat was observed to be higher during the Overall Period compared to Period-I and Period-II. These findings support the investigation carried out by Tewari *et al.* (2017), who analyzed the growth and instability of wheat in terms of area, production, and yield in Uttar Pradesh.

Table 3: Measure of instability in Area, Production and Yield of Wheat

Crops Instability index	(In Percent)								
	Period-I			Period-II			Overall-Period		
	(2001-2011)			(2012-2022)			(2001-2022)		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
CDVI	9.62	12.73	4.66	6.89	9.98	6.13	13.70	24.62	12.08

2. Instability in Area, Production and Yield of Bajra Crop in Rajasthan

(i) Area:

Table 4 provides insights into the instability in the bajra crop. During Period-I, the state exhibited less variation in bajra crop according to the Cuddy-Della-Valle index (CDVI) at 12.47%. Similar observations were reported in Period-II and the Overall Period in the state. In Period-II, the instability was 6.78%. In the Overall Period, the area for bajra crop showed lower instability at 6.10%.

(ii) Production:

During Period-I, higher variations were observed in the state for bajra production, according to the Cuddy-Della-Valle index (CDVI) at 45.23%. In

Period-II, the instability was 11.49% for CDVI. In the Overall Period, CDVI values of 9.96% indicated that bajra production exhibited lower instability.

(iii) Yield:

During Period-I, higher variations were observed in the state for bajra yield at 37.08%. In Period-II, the instability was 8.35% and in the Overall Period, instability of 18.55% was spotted.

The variability in the area, production, and yield of bajra was higher in Period-I compared to Period-II and the Overall Period during the study period. These conclusions are coherent with the analysis carried out by Byaligoudra *et al.* (2019), who examined instability in terms of area, production, and yield of bajra in Andhra Pradesh.

Table 4 : Measure of Instability in Area, Production and Yield of Bajra

(In Percent)

Crops Instability index	Period-I			Period-II			Overall-Period		
	(2001-2011)			(2012-2022)			(2001-2022)		
	Area	Production	Yield	Area	Production	Yield	Area	Production	Yield
CDVI	12.47	45.23	37.08	6.78	11.49	8.35	6.10	9.96	18.55

Analysis of Trend in Area, Production and Yield of Major Cereals in Rajasthan:

The analysis investigated the trends in the area, production, and yield of major cereals in Rajasthan from 2000-01 to 2021-22. For each commodity, the trend analysis encompassed the examination of trends across different time periods in area, production, and yield. The significance of the trend equation was evaluated using the 'P value' method. This portion presented trends observed for the selected major cereals.

1. Trend in Area, Production and Yield of Wheat:

- (i) **Area:** Examination of Table 5 revealed that the coefficient of determination (R-squared) for the wheat area was 0.75, indicating that the quadratic equation accounted for 75% of the instability in the data. While this suggested a moderate fit, it falls short of the desired level of accuracy. The p-value of 0.002 indicated statistical significance, albeit not as high as desired, implying that the

quadratic model explained a significant portion of the variation in wheat cultivation area but may not capture all underlying complexities. The negative coefficient (x^2) suggested a significant decrease in the area under wheat cultivation over the study period.

- (ii) **Production** : From Table 5, it became apparent that the coefficient of determination (R-squared) for wheat production was 0.832, signifying that the quadratic equation provided a superior fit for explaining the instability in wheat production. This suggested that approximately 83.2% of the variation in production was accounted for by the quadratic model. The p-value of 0.026 indicated statistical

significance, although marginally lower than that observed in the yield model.

- (iii) **Yield** : It was observed that the coefficient of determination (R-squared) for wheat yield was 0.828, indicating that the linear model explained approximately 82.8% of the instability in yield which was significant. This suggested that the linear equation provided a robust fit for predicting variations in yield. Additionally, the positive coefficient (x) suggested a significant enhancement in wheat yield over specified period. Similar findings were reported by Kumari *et al.* (2020), who detected a substantial rise in wheat yield with a relatively high R-squared value during the study period.

Table 5 : Estimated Trend Equations of Area, Production and Yield of Wheat

Particulars	Functional forms	Equations	R ²	P value
Area	Quadratic	$Y = -5.368x^2 + 181.3x + 1585.9$	0.750	0.002
Production	Quadratic	$Y = -15.943x^2 + 717.61x + 3751.8$	0.832	0.026
Yield	Linear	$Y = 0.0617x + 2.6065$	0.828	0.001

2. Trend in Area, Production and Yield of Bajra:

Table 6 illustrates the trend in the area, production, and yield of bajra in Rajasthan from 2001 to 2022.

- (i) **Area**: Among the models employed for analysis, the cubic equation provided the best fit for bajra's area under cultivation. With an R-squared value of 0.342, it explained approximately 34.2% of the instability in bajra's cultivation area. The negative coefficient (x^2) indicates a decrease in bajra crop during the specified time, particularly in the year 2022.

- (ii) **Production** : Among the models analyzed, the exponential equation emerged as the best-fit model for bajra's production. However, it demonstrated a relatively weaker fit with an R² value of 0.158, describing around 15.8% of the instability in bajra's production. The positive coefficient indicated an improvement in bajra's production level over the specified time.

- (iii) **Yield** : The linear equation emerged as the best-fit model for analyzing bajra's yield among the other models utilized for analysis. It exhibited an R-squared value of 0.412, explaining

approximately 41.2% of the instability in bajra's yield. The negative coefficient (x^2) suggested a slight decrease in the yield of bajra crop specifically in the year 2022.

The trend analysis indicated an overall

increase in production for the bajra crop, except for the year 2022 where a decline was observed. Analogous conclusions were reported by Kumari *et al.* (2020), who noted a significant decline in bajra.

Table 6 : Estimated Trend Equations of Area, Production and Yield of Bajra

Particulars	Functional forms	Equations	R ²	P Value
Area	Cubic	$Y = 0.7256x^3 - 30.068x^2 + 308.25x + 4105.9$	0.342	0.153
Production	Exponential	$Y = 2548.7e^{0.0271x}$	0.158	0.067
Yield	Quadratic	$Y = -0.0003x^2 + 0.0315x + 0.5094$	0.412	0.261

Evaluation of the Relative Impact of Cultivated Area and Yield on the Expansion of Agricultural Production

Decomposition analysis offers several advantages over growth analysis, including its ability to identify the fundamental elements crucial for estimating output, restructuring development strategies for governmental implementation, and setting targets for specific agricultural commodities to achieve higher output growth rates while recognizing trade-distorting factors.

Minhas & Vaidyanathan Decomposition Model (1965) was utilized to identify the factors contributing to output growth. This analysis was conducted for two distinct sub-periods (Period-I: 2000-01 to 2010-11, Period-II: 2011-12 to 2021-22) as well as for the Overall-Period from 2000-01 to 2021-22. The sources of growth are classified into three effects: Yield Effect, Area Effect, and Interaction Effect. A higher percentage of a parameter indicated a greater contribution to output growth.

1. Sources of Output Growth in Wheat Crop

Table 7 presents a decomposition

analysis of the factors driving wheat production growth.

During Period-I, the yield effect exhibited a positive value of 40.55%, indicating a significant contribution of increased wheat yield per unit of land to the growth in wheat production. Similarly, the area effect was positive at 47.97%, suggesting that the expansion of cultivated land area for wheat also performed a substantial function in improving wheat production. The interaction effect was positive with a value of 11.48%, indicating that the combined impact of changes in yield and area contributed positively to wheat output growth in this period.

During Period-II, the yield effect was negative at -181.76%, indicating a decline in wheat yield per unit of land, which significantly impacted wheat production negatively. Conversely, the area effect was highly positive at 253.08%, indicating a substantial improvement in the land area dedicated to wheat cultivation. This expansion performed a major function in driving

the growth of wheat production. The interaction effect was also positive with a value of 28.67%, suggesting that despite the negative yield effect, the overall impact of interactions between yield and area remained positive.

Over the Overall-Period, the yield effect remained positive at 69.12%, indicating that, on an average, increased yield per unit of land contributed to the overall growth in wheat production. The area effect was positive at 22.04%,

highlighting the ongoing contribution of expanded cultivated land areas to the overall wheat production growth. The interaction effect was positive at 8.84%, demonstrating a positive synergy between changes in yield and area that promoted the overall growth in wheat production. Kumar and Shekhar (2017) also found positive results in wheat crop in terms of area, yield, and interaction effect during the period 2001 to 2016 in India.

Table 7 : Sources of Output Growth in Wheat Production

(In Per cent)

Periods	Yield Effect	Area effect	Interaction Effect
Period-I (2000-01 to 2010-11)	40.55	47.97	11.48
Period-II (2011-12 to 2021-22)	-181.75	253.08	28.67
Overall-Period (2000-01 to 2021-22)	69.12	22.04	8.84

2. Sources of Output Growth in Bajra Crop

Table 8 presents a decomposition analysis of the sources of output growth in bajra production. During Period-I (2000-01 to 2010-11), the yield effect was notably positive at 71.88%, indicating a substantial increase in bajra yield per unit of land, which significantly contributed to production growth. The area effect was also positive, though to a lesser extent, at 14.92%, suggesting some expansion in cultivated land area for bajra production during this period. The interaction effect, with a positive value of 13.20%, further highlighted the combined positive impact of changes in yield and area on bajra production growth.

In Period-II (2011-12 to 2021-22), the yield effect turned negative at -50.59%,

indicating a decline in bajra yield per unit of land, which negatively impacted production. However, the area effect was highly positive at 137.65%, signifying a substantial increase in cultivated land area contributing to production growth. The interaction effect, with a positive value of 12.94%, suggested that despite the negative yield effect, the overall impact of interactions between yield and area remained positive, albeit to a lesser extent compared to Period-I.

Throughout the time span from 2000-01 to 2021-22, there was notably a positive yield effect of 153.26% in Bajra production, indicating a substantial rise in Bajra yield per unit of land, thus contributing significantly to overall production growth. Conversely, the area effect showed a negative value of -

23.48%, signifying a decrease in the cultivated land area for Bajra production over the entire period, which had an adverse impact on production growth.

The interaction effect, at -29.78%, demonstrated a negative synergy between changes in yield and area, further contributing to the overall decline in production growth.

Table 8 : Sources of Output Growth in Bajra Production

(In Per cent)

Periods	Yield Effect	Area effect	Interaction Effect
Period-I (2000-01 to 2010-11)	71.88	14.92	13.20
Period-II (2011-12 to 2021-22)	-50.59	137.65	12.94
Overall-Period (2000-01 to 2021-22)	153.26	-23.48	-29.78

CONCLUSION

This research paper examined the production performance of two major cereals, wheat and bajra (pearl millet), in the state of Rajasthan, India, spanning the period from 2000-01 to 2021-22. Utilizing secondary data from reputable sources such as Rajasthan Agricultural Statistics and the Ministry of Agriculture and Farmers Welfare, the study employed various analytical techniques to assess the growth, instability, trends, and decomposition in wheat and bajra cultivation. The findings revealed significant growth in both wheat and bajra production during the initial period (2000-01 to 2010-11), followed by changing trends in subsequent years. While wheat cultivation exhibited non-significant growth in the latter period (2011-12 to 2021-22), bajra production-maintained growth despite a decline in cultivation area. Decomposition analysis highlighted the dominant role of yield in driving production growth for both crops, emphasizing the importance of yield-enhancing interventions. Overall, this study presented production dynamics of major cereals in Rajasthan, offering a foundation for informed policy interventions aimed at

sustainable agricultural development in the region.

The significant growth in wheat and bajra production during the initial period highlighted the potential for increasing cereal yields in the region. However, the non-significant growth in wheat production and the decline in bajra cultivation area in the latter period signal challenges that need to be addressed to ensure continued productivity growth. Analysis also revealed moderate instability in wheat production with relatively stable yields but higher instability in bajra production. Trend analysis indicated a decrease in wheat cultivation area but overall increase in production and yield, while bajra cultivation area declined with fluctuating production levels. Decomposition analysis highlighted the positive contributions of yield and area effects to wheat production growth, contrasting with positive yield effects but negative area effects leading to an overall decline in bajra production growth. Policy measures including enhanced research, infrastructure development, crop diversification, capacity building, market linkages, policy support, and risk management are suggested to improve cereal production and ensure food security in Rajasthan.

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Development and standardisation of purple yam waffles

Ch. Keerthi¹, N. Haripriya² and M.Niharika^{*3}

^{1,2&3}Department of Home Science, Sri Padmavati
Women's University, Tirupati, Andhra Pradesh, India.

*Email : niharika.bamli@gmail.com

ABSTRACT

Purple yam (*Dioscorea alata* L) is a food that has the potential as a source of natural antioxidants, because of the anthocyanin component. Among the many therapeutic uses of purple yam include enhancing blood circulation and reduces asthmatic symptoms. In addition to these benefits, they are also used in the manufacturing a wide range of food items, including ice cream, waffles, jam, and buns. This study aims to develop a Purple yam waffles. The main ingredients that go into making these waffles are purple yam, sugar, Maida, baking powder, ordinary yam, and strawberry flavor. The levels of anthocyanins, total phenol, antioxidant activity, and darker color increased with the addition of purple yam flour. However, the addition of purple yam flour did not affect the level of preference for the waffle produced. Three different versions of the waffles were developed and to study the organoleptic acceptability. The organoleptic study yielded good results for variation 1. The nutritional value of the one waffle (75g) is 446.38 kcal, 1.78 g fiber, 11.4 g protein, 10.7g fat and 36.4 mg calcium, 93.3mg phosphorous , 31.82 mg anthocyanin, 36 mg total phenols

Keywords : Purple yam, Anthocyanin , Health benefits, Waffles, Organoleptic evaluation, Nutrient composition.

INTRODUCTION

Purple yam are one of the varieties of tubers that have the potential as a source of local food ingredients that contain carbohydrates, proteins, fats, fiber, vitamins, minerals, and contain antioxidants [Indrastuti 2012]. Purple yam plants grow in the Soppeng area, but the people do not use these plants, even though purples can be processed into flour to extend shelf life and can be used as an alternative to reduce wheat flour in meeting consumer needs. The advantages of this processed flour can be seen from its form, among

others, easily stored ingredients, small volume, easy to transport, and can be used for various processed food products [Tejasari et.al 2001]. Another interesting thing from the *Dioscorea* plant is that it contains anthocyanin compounds and antioxidant activity.

According to [Fang et.al 2011], the purple color found in local varieties of tuber indicates that there is an anthocyanin which is an antioxidant and can counteract free radicals in the body. Anthocyanin content has colored compounds which are mostly red, blue and purple. Strong purple color shows

anthocyanin levels and has high antioxidant activity [Krisnawati 2009]. Antioxidants are compounds that serve as a neutralizing increase in free radicals, protecting cells from the toxic effects produced and contributing to disease prevention. Anthocyanin acts as an antioxidant that can counteract free radicals so as to prevent aging, cancer and other degenerative diseases. Anthocyanin content also functions as antimutagenic, antocarcinogenic and can reduce blood sugar levels and antihypertension [Jusuf et.al 2008]

Purple yam contains high energy content, various vitamins, minerals, and anthocyanins. Anthocyanins have been associated to a lower risk of premature ageing, cognitive decline, polyps, gout, stomach acid, coronary heart disease, and cancer. In addition, it also acts as an anti-inflammatory, anti-diabetic, and anti-obesity. It shows that purple yam is good for daily consumption and could be part of the local crop that can benefit human health. Waffles are popular snack foods among people. Manufacturers use many plant sources to produce waffles. Despite this, there has been minimal attempt to employ purple yam as the principal component in waffle manufacture. As a result, the main focus of this study was purple yam waffles. Therefore, it is important to analyze the waffles nutritional contents and sensory evaluation, shelf life (microbial analysis) of the product.

MATERIALS AND METHODS

RAW MATERIALS

The ingredient used for the development of waffles was Purple yam which was purchased online. The purple yams were first scrubbed before being peeled and boiled till

tender. The fleshs were mashed with the masher and their weight was calculated using the conventional procedure. The remaining ingredients like straw berry, maida, butter and sugar were purchased from local markets of Tirupati.



Fig:1 PURPLE YAM

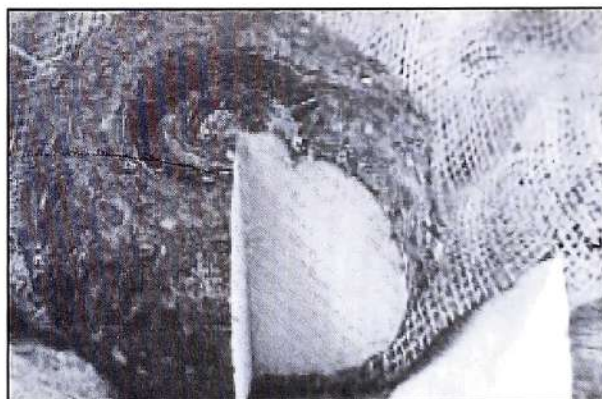


Fig:2 NORMAL YAM



Fig:3 STRAW BERRY



Fig:4 SUGAR POWDER

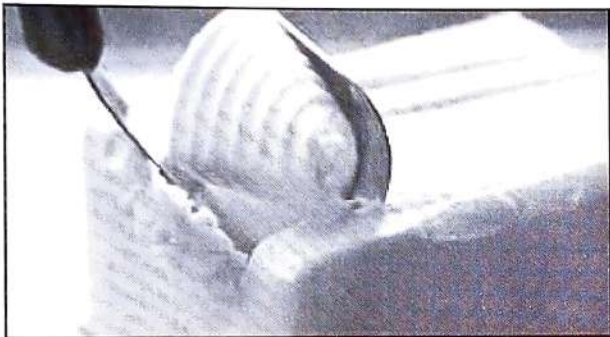


Fig:5 BUTTER



Fig:6 MAIDA

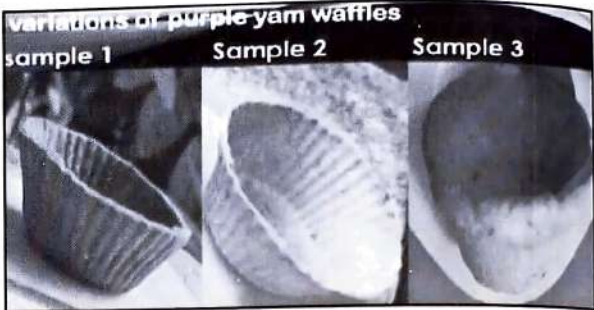


Fig:7 VARIATIONS OF EDIBLE WAFFLES
METHODS

Purple yam edible yam waffles processing and preparation:

The three main waffle recipes are listed in Table 1. The total mass of each formula is 100 g. Fine ingredients were selected for the development of product. The purple yam was peeled to separate the tuber meat and skin to lessen contamination. After being peeled and boiled for ten minutes, the purple yam was mashed into a paste. Then add maida, sugar, butter, baking soda, and yam flour in various ratios and prepare dough, shaping them into round soft balls and then into cups, transferring them into silicon moulds, adding weight to help them maintain their shape, and baking them for fifteen minutes at 150 degrees Fahrenheit produced perfect waffles.

Table 1: Purple yam waffles formulation with three distinct versions

INGREDIENTS	TRIAL-1	TRIAL-2	TRIAL-3
PURPLE YAM	30 grams	50 grams	0
NORMAL YAM	0	0	50 grams
STRAWBERRY FLOUR	20 grams	0	0
SUGAR POWDER	25 grams	25 grams	25 grams
MAIDA	20 grams	20 grams	20 grams
BAKING POWDER	5 grams	5 grams	5 grams
TOTAL	100 grams	100 grams	100 grams

Panel Judges' Sensory Evaluation of the Product:

Five-point hedonic measures were employed to assess acceptance. It is one of the tests that judges use to provide evaluation scores based on the ratings for the sensory attributes listed on the designated score card. They were given separate sheets with their feedback on the product's upgrades. The panelists used the given instructions to do a sensory evaluation of the product before to each session. Score cards were provided for each trial individually.

PACKAGING

The role of packing helps grab the audience's attention, its significance has increased. Packaging is one of those that marketers can use to make a customer more likely to buy a

product. Overuse of packaging is done for information transfer and convenience. Instructions on how to use, recycle, transport, or dispose of a package or product is provided on labels and packages. Careful packing was used to keep the product fresh for a while.

MARKETING

The waffles are distinctive as is and accessible even in local markets. They also have a lengthy shelf life and are simple to transport. These waffles are cheap and a hit with most kids. Because purple yam, which has antioxidants and other nutrients, is used to make them, they are also very nutrient-dense. Consequently, there would be a significant market demand for these waffles.

FIG 8: FLOW CHART OF DEVELOPMENT AND STANDARDISATION OF PURPLE

YAM EDIBLE YAM WAFFLES

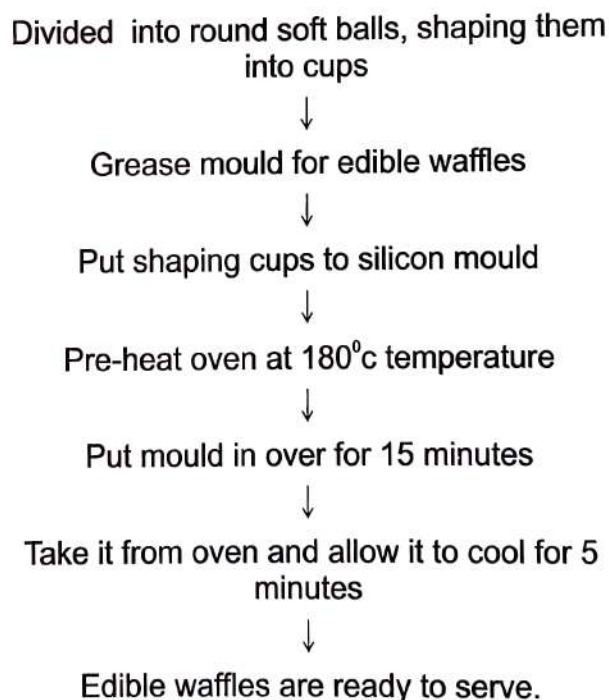
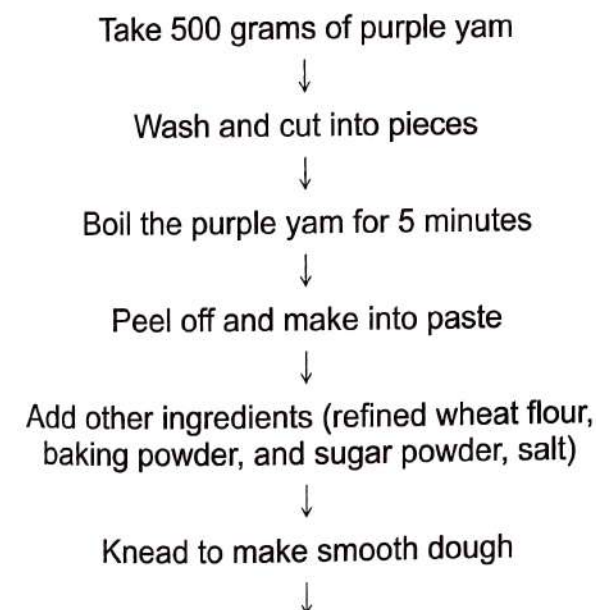


FIG 9: LABELLING OF PURPLE YAM EDIBLE WAFFLES



LABELLING : Following the packaging procedure, the product's specs were listed on the label. The cost estimation process often covers how the resources are used. There are three levels of costing studies, for example,

COST EVALUATION:

Obtaining assets for usage within a single agency. Distinguishing the costs of distinct

arbitrations between two or more activities. More comprehensive analysis of the full social cost implications of various arbitrations.

Cost aspects of purple yam edible waffle:

Weight of 1 purple yam edible waffle = 10 grams

1 kg of purple yam dough produces 100 edible waffles

Table 2 : Cost of making purple yam edible waffle

	INGREDIENT	Quantity in grams	Cost
A	Raw material		
	Purple yam	300	Rs.60/-
	Strawberry powder	200	Rs.275/-
	Sugar powder	250	Rs. 10/-
	Maida	200	Rs. 15/-
	Baking powder	50	Rs.15/-
	Total	1000	Rs. 375/-
B	Equipment		Rs. 100/-
C	Labour charges		Rs. 100/-
D	Miscellaneous		Rs. 10/-
	A+B+C+D		Rs. 585/-

The data in Table 2 shows the cost of 100 purple yam edible waffles which included

cost of raw ingredients, equipment, labor and miscellaneous. Thus, the cost of 1 edible waffle is Rs.5.8 per waffle.

RESULTS AND DISCUSSION

TABLE 3 : NUTRIENT COMPOSITION OF PURPLE YAM EDIBLE WAFFLES

Ingredients	QUANTITY gm	Protein gm.	CALCIUM mg	PHOSPHOROUS mg	β - CAROTENE mg	Total Phenols mg	Anthocy Anins mg
VARIATION1	75	11.46gm	36.44mg	93.3mg	0.2mg	36	31.82
VARIATION2	75	3.66gm	34.44mg	64.3mg	0.2mg	31	31.5
VARIATION3	70	2.85gm	12.54mg	35.93mg	09.3mg	13	6.8

The results presented in Table 3 showed that the protein content of variation-1 (11.46g) is higher than that of the variation 2 and 3. It was observed that calcium content was high in variation - 1 (332.44mg) followed by variation - 2 and 3 respectively. However, the β -carotene, and Anthocyanins content of the waffles are not producing a noticeable changes. Total Phenols content is also rich in variation -1 compared to other variations (2 and 3). The results of the phenol content in the formulated waffle showed that the baking temperature treatment had no effect on the phenol content, while the addition of purple yam had an effect on the phenol content. The total phenol content of plain bread further increased with the addition of yam. Studies of [Tamaroh *et.al* 2017] showed the total phenol content in purple yam flour (454.67 mg GAE/100g db). In a previous study, [Hong and Koh 2016] stated that the baking processing method has no effect on the total phenolic content of purple yam.

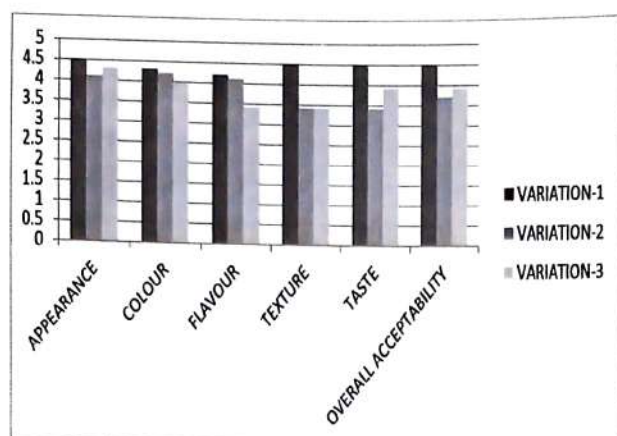
The formulation has been standardized by repeating lab trials and examining the organoleptic qualities with semi-trained panel members. Variation -1 is the final product recommended by the panel members.

Table 4 shows the acceptance values for the organoleptic evaluations and mean scores for the production of edible waffles and display the average score for each aspect of the product.

There are various stages involved in new product development, the most important of which is the tasting panel stage. Various product attributes including as appearance, color, taste, flavor, and texture are staged in the tasting panel. Variation 1 has a better appearance, taste, color, flavor, texture, and general acceptability than the other varieties. The edible waffles with strawberry flavoring and purple yam have the right taste. It was stated that the flavor of strawberry with purple yam might be increased or decreased.

TABLE : 4 Sensory Evaluation of Edible Waffles

ATTRIBUTES	VARIATION 1	VARIATION 2	VARIATION 3
APPEARANCE	4.5 $\pm$ 0.52	4.1 $\pm$ 0.56	4.3 $\pm$ 0.48
COLOUR	4.3 $\pm$ 0.48	4.2 $\pm$ 0.42	4.0 $\pm$ 0.66
FLAVOUR	4.2 $\pm$ 0.42	4.1 $\pm$ 0.56	3.4 $\pm$ 0.69
TEXTURE	4.5 $\pm$ 0.70	3.4 $\pm$ 0.69	3.4 $\pm$ 0.69
TASTE	4.5 $\pm$ 0.70	3.4 $\pm$ 0.96	3.9 $\pm$ 0.87
OVERALL ACCEPATABILITY	4.5 $\pm$ 0.52	3.9 $\pm$ 0.56	3.9 $\pm$ 0.56



Variation-1 offers the best colour, appearance, texture, taste, and general acceptance of the three versions. The panel members who sampled the three variations appreciated and rated variation 1 as the best of the three variations. Additionally, variant 1 had the highest nutrient composition, particularly in nutrients such as calcium, phosphorus, and protein.

Purple yam is gaining popularity as a nutritious and functional ingredient in food products. This promotes the creation of new branded healthy and functional foods. The anthocyanin content in this entices food technologists to fully investigate its capabilities in the commercial food processing sector. Today, a large section of the population suffers from blood circulation, digestion, cough, ulcers, and other ailments.

As a result, there is a necessity to cure the patients using natural methods. It has skin and hair advantages in addition to being a fantastic anthocyanin-containing meal.

Microbial analysis of developed edible waffles:

Microbial estimation of product may provide information concerning the quality of the food Material. The sanitary conditions under which the product was processed and effectiveness of the method of preservation. Estimation of the total number of organisms in ingredients involves basically the same procedure.

The waffles are packed and sealed in aluminum foil and packed in sealed plastic bag. The product was drawn for analysis at 15 days; 30 days and 90 days. The samples were analyzed for yeast and mould, total plate count. (Aneja, 2005).

The serial dilution is a common technique used in immunologic procedures. A small amount of serum or solute can be serially diluted by transferring aliquots to dilute. One of the most common serial doubles the dilution factor with each transfer (1:2, 1:4, 1:8,). These dilutions can be done in microtiter plates or test tubes depending on the volume of the sample and diluents used. (Booth 2006)...

Table 5 : Microbial analysis of edible waffle at different storage periods.

Test parameter	15 th day	30 th day	90 th day	Test method
Total plate count	Nil	Nil	1.3×10 ³ CFU/g	Is 5402:2012 (RA:2018)
Total yeast and mould count	Nil	Nil	<1 CFU/g	ISO 4883:2003 IS 5403:1999 (RA:2005)

As these waffles are made from purple yam, Maida, microbial analysis was done to know the Microbial count of purple yam edible waffles. In this Microbial analysis test was done according to parameters, the samples are kept in incubator for 24 hours. Data in table no.5 Shows the total plate count and the yeast and mould count were performed for edible waffle of regular interval of 15th day of period up to 90th day of storage period. The total plate count was nil at initial day to 30th day, Microbial count observed in 90th day. The results of shelf life studies showed that purple yam edible waffle doesn't have any microbial contamination & it is considered safe to use. The products are stored for 6 months without any microbial spoilage at room temperature if stored carefully without any contamination or rodent contamination. The present study results are on par with the study results of Gerald et.al (2018), who stated that the microbial action in biodegradable and non-biodegradable and concluded that the microbial range in biodegradable products were 63 to 110 cfu per gram. When compared to the above study, the developed edible waffles had an acceptable level of microbial count.

CONCLUSION

The study discovered that purple yam, yam, and strawberry flavours are employed to make palatable waffles. The edible waffles had an adequate amount of antioxidants, vitamins, and minerals and were appropriate for feeding children of all ages. The production process is cost-effective and simple to use on a small and big industrial scale. Sensory, packing, and storage tests show that the purple yam-based product has

a high overall acceptance. Because of the presence of many substances in it, edible waffles are beneficial to persons suffering from osteoporosis, skin and hair problems, and also to enhance gut health and digestion.

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Optimization and development of plant based meat analogue formulations

Megha Humane^{1*} and Vishal Parate²

^{1&2}Department of Food Technology, University Institute of Chemical Technology, Kavayitri Bahinabai Chaudhari North Maharashtra University, Jalgaon (M.S), India

*Email : meghah14@gmail.com

ABSTRACT

A meat analogue is a meat-like substance made from plants and made to look, taste, smell and feel like meat. The main function of meat analogue is to replace meat in the diet. This study was aimed at introducing the potential of soybean, chickpea, mushrooms and jackfruit to develop a healthy meat analogue. The central composite design of response surface methodology (RSM) was used for designing the 24 experimental formulations for the development of meat analogues with said protein sources and coded as S1 to S24. The steaming method was used to texturize all the 24 formulations produced. All the texturized samples were then examined for various textural properties using texture analyzer. On the basis of overall textural properties (hardness, adhesiveness, cohesiveness, springiness, gumminess and chewiness) of textured samples comparing with controlled sample (goat meat) 16 samples were screened out. The selected 16 samples were then analyzed for proximate composition (moisture content, fat content, ash content, fiber content, protein content and carbohydrate) and 8 samples were selected comparing with controlled sample (goat meat) on the basis of protein content for further screening of samples as per sensory evaluation. The sensory evaluation of chosen 8 samples was carried out using 9 point Hedonic scale with semi-trained panel. Eventually samples S2, S8, S19, and S22 were screened out on the basis of sensory evaluation. The work thus concludes that if formulated properly, it is possible to prepare acceptable quality meat analogue using defatted Soy flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour as vegetarian protein source. The selected samples S19, S2, S8 and S22 can be used as goat meat replacer as carries good texture, high protein and acceptable organoleptic characteristics.

Keywords: Soybean, Mushroom, Jackfruit, Chickpea, Response surface methodology, Texture

INTRODUCTION

A meat analogue is a plant-based meat substitute, also known as vegan meat, fake meat, mock meat, meat alternative, imitation meat, or vegetarian meat. Meat analogues are goods that perform similarly to meat, have similar physical and sensory characteristics, and can be prepared by consumers just like meat. Meat analogue provide good source of protein and amount of

protein vary from product to product. In many nations, a combination of population health awareness and sustainable food has led to the development of plant protein-based meat analogue. In terms of sustainability, meat production has aided environmental change and resource depletion. Animal diseases, healthier diets, a high need for healthful and holy food, and economic concerns have all influenced the usage of vegetable proteins in food items over time (Joshi & Kumar, 2015).

Many strategies have been created to help people cut back on their meat consumption; the first strategy is to substitute vegetables, beans, pulses, and/or nuts for meat in a meal. The second strategy relies on the creation of structured products. Tofu, tempeh, and seitan, which have been produced and consumed for generations in East Asia, are examples of goods with a traditional structure. However, in western nations, consumer acceptability of these products is lower. As a result, a new class of structured items known as meat analogues has arisen. Recently, there have been increased studies of plant-based meat analogue as an alternative protein source to substitute the traditional animal-based food in various parts of the world. This may be due to the rising world population and limited natural resources, causing animal meat production to be an unsustainable practice (Dekkers *et.al.*, 2018). Some plant proteins, particularly soybean protein, are already used in meat products. Despite being one of the most popular legumes in the world and an excellent, affordable source of high-quality protein, relatively little research has been done on the use of chickpea flour in meat preparations. Additionally, protein products from animal-based sources such as milk and eggs and from new sources such as fungi (mushroom) and bacteria are available now a day's (Wild *et.al.*, 2014). In meat products, jackfruit was used instead of chevon in proportions of 10%, 20%, and 30% weight to weight (Verma *et.al.*, 2015).

The aim of this study is to optimize the formulations using plant based protein sources like defatted Soy flour, Kabuli Chickpea flour, Jackfruit flour and Button Mushroom for the development of meat analogue.

MATERIALS AND METHODS

Procurement of raw materials

Raw materials used for the preparation of meat analogue were Kabuli Chickpea, Jackfruit, white button Mushroom purchased from local market of Jalgaon, Maharashtra India. Defatted Soy cake received from Sanjay Soy Pvt. Ltd. Industry, Avdhan MIDC, Dhule Maharashtra India, to make Defatted Soy flour. Binding agent carrageenan of brand IAMPURE and guar gum of brand NATURE'S HARVEST were used in the formulation.

Proximate analysis of raw protein sources

Proximate analysis of Defatted Soy flour, Kabuli Chickpea, Button Mushroom and Jackfruit were carried out as per AOAC method for moisture, protein, fat, ash, crude fiber and carbohydrate (AOAC, 2000).

Processing of Protein Sources

Major raw material Defatted Soy flour, Kabuli Chickpea and Jackfruit were used in the form of flour.

Defatted Soy flour

Defatted Soy coarse flour was ground in lab grinder into fine flour to make Defatted Soy flour.

Kabuli Chickpea flour

Kabuli Chickpea flour process was made by modifying a method given (Ravi & Harte, 2009). Around 10% water was added to Kabuli Chickpea seeds and mixed thoroughly for uniform moisture penetration into the cotyledons, followed by an equilibrium period of about 2 hrs. The moistened seeds were then dried at 45–50°C for 6 hrs in lab hot air oven. Splitting of seeds was carried out by

milling with household dhal mill and separated by manual winnowing into different fractions such as dhal, partially dehulled whole grains, husk, broken seeds and some flour. The obtained dhal (dehulled grain) is then milled to obtain fine flour.

Jackfruit flour

Jackfruit flour was made by process mentioned (Hyndavi *et.al.*, 2022). The collected tender Jackfruit was thoroughly cleaned with 0.1 % KMS to remove any dirt or dust particles adhered to the surface. Outer green rind was removed by knife manually and tender Jackfruit was made into slices. Tender Jackfruit slices then were blanched in boiling water for one minute. The tender jackfruit slices were dried by using tray drying method at 60°C in hot air oven till it dried and dried slices were then finely ground to obtained flour.

Mushroom paste

Mushroom paste was made by process mentioned by previous research study (Mishra & Mani, 2019; Kumar *et.al.*, 2014; Rosli & Solihah, 2014; Rosli *et.al.*, 2011). The white button Mushroom was first rinsed with water and subjected to blanching (in boiling water for 5 min.) and chopped coarsely and ground to paste in lab grinder.

Experimental method

Experimental design Central composite rotatable design (CCRD) (Ahrwar *et.al.*, 2015) was applied to determine the best formulation of Mushroom paste, Jackfruit flour, kabuli chickpea flour and defatted soy flour to optimize the ingredients combination for the development of meat analogue using software State-Ease (Design Expert version 13.0.0.5) as shown in Table 1. Mushroom, Jackfruit flour, Kabuli Chickpea flour and Defatted Soy flour were taken as independent variables and protein content,

cohesiveness, adhesion, hardness, gumminess, springiness, chewiness and overall acceptability as responses. RSM of central composite design helped to illustrate the factor interactions and influence of percentage of defatted Soya flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour on texturized meat analogue formulations

Preparation of the product

All the raw materials were weighed according to formulation obtained by Experimental Design and mix together by adding binding agent carrageen and guar gum and some amount of water to make into dough. After dough making, the meat analogue formulations were texturized by steaming method for 20 min. and cooled (Mishal *et.al.*, 2022; Kumar *et.al.*, 2012). All the textured meat analogue formulations were then subjected for further analysis.

Texture profile analysis (TPA)

The textural characteristics of the 24 textured meat analogue formulations in terms of hardness, chewiness, springiness, cohesiveness, adhesiveness and gumminess were established using cylindrical probe of Texture Analyzer (Texture Pro CT V1.7 Build 28 Brookfield Engineering Labs. Inc.). Out of these 24 meat analogue formulations, 16 meat analogue samples were chosen based on the comparison of textural parameters with control S0 (goat meat).

Proximate analysis of textured meat analogue formulations

The AOAC method was used to determine the proximate composition of 16 selected meat analogue samples for moisture, protein, fat, carbohydrate, and total ash. On the basis of protein content 8 meat analogue samples were screened out comparing with control S0 (goat meat).

Sensory Evaluation

Sensory evaluation of preferred 8 meat analogue samples were carried out by 10 semi-trained panelists on a 9 point Hedonic scale (9-like extremely to 1-dislike extremely) as mentioned (Ranganna, 1999), to establish the overall acceptability of the products. On the basis of overall acceptability 4 meat analogue samples were selected.

Response surface design plot

The effect of composition of plant based meat sources (defatted Soy flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour) in the formulations on the various characteristics (texture, protein content and overall acceptability) of developed meat analogues was qualitatively studied using Response surface methodology (central composite design) that demonstrated the factor interactions and influence of the

composition of defatted Soya flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour on the various textural parameters (hardness, adhesiveness, cohesiveness, springiness, gumminess and chewiness), proximate composition (protein content) and sensory (overall acceptability) of developed meat analogue.

RESULTS AND DISCUSSION

Table 1 is representing the design of experiment for the development of meat analogue and shows experimental levels of independent variable in terms of actual and coded factors. The code assigned for protein sources were, A: Defatted Soy flour, B: Kabuli Chickpea flour, C: Mushroom paste, D: Jackfruit flour. The different formulations had been coded from S1 to S24.

Independent variables	Factor levels				
	Min.	Max.	low	High	Mean
A:Defatted soy flour	25	50	12.5	62.5	37.5
B:Chickpea flour	25	50	12.5	62.5	37.5
C:Mushroom paste	25	50	12.5	62.5	37.5
D:Jackfruit flour	25	50	12.5	62.5	37.5

Table 1 : Design of experiment for the development of meat analogue formulations

Run	Sample Code	Factor 1 A:Defatted soy flour	Factor 2 B:Chickpea flour	Factor 3 C:Mushroom paste	Factor 4 D:Jackfruit flour
1	S1	25	25	25	25
2	S2	50	25	25	25
3	S3	25	50	25	25
4	S4	50	50	25	25
5	S5	25	25	50	25
6	S6	50	25	50	25
7	S7	25	50	50	25
8	S8	50	50	50	25
9	S9	25	25	25	50
10	S10	50	25	25	50

Run	Sample Code	Factor 1 A:Defatted soy flour	Factor 2 B:Chickpea flour	Factor 3 C:Mushroom paste	Factor 4 D:Jackfruit flour
11	S11	25	50	25	50
12	S12	50	50	25	50
13	S13	25	25	50	50
14	S14	50	25	50	50
15	S15	25	50	50	50
16	S16	50	50	50	50
17	S17	12.5	37.5	37.5	37.5
18	S18	62.5	37.5	37.5	37.5
19	S19	37.5	12.5	37.5	37.5
20	S20	37.5	62.5	37.5	37.5
21	S21	37.5	37.5	12.5	37.5
22	S22	37.5	37.5	62.5	37.5
23	S23	37.5	37.5	37.5	12.5
24	S24	37.5	37.5	37.5	62.5

*Above formulation include binding agent (carrageenan and guar gum) 0.5% each and water (as per need)

The above protein sources composition of formulations (S1 to S24) were converted into percent (%) and are shown in Table 2.

Table 2: Percent Composition of protein sources in meat analogue formulations

Run	Sample code	Factor 1 A:Defatted soy flour	Factor 2 B:Chickpea flour	Factor 3 C:Mushroom paste	Factor 4 D:Jackfruit flour
1	S1	25	25	25	25
2	S2	40	20	20	20
3	S3	20	40	20	20
4	S4	33.3	33.3	16.7	16.7
5	S5	20	20	40	20
6	S6	33.3	16.7	33.3	16.7
7	S7	16.7	33.3	33.3	16.7
8	S8	28.6	28.6	28.6	14.2
9	S9	20	20	20	40
10	S10	33.3	16.7	16.7	33.3
11	S11	16.7	33.3	16.7	33.3
12	S12	28.6	28.6	14.2	28.6
13	S13	16.7	16.7	33.3	33.3
14	S14	28.6	14.2	28.6	28.6

Run	Sample code	Factor 1 A:Defatted soy flour	Factor 2 B:Chickpea flour	Factor 3 C:Mushroom paste	Factor 4 D:Jackfruit flour
15	S15	14.2	28.6	28.6	28.6
16	S16	25	25	25	25
17	S17	10	30	30	30
18	S18	35.71	21.43	21.43	21.43
19	S19	30	10	30	30
20	S20	21.43	35.71	21.43	21.43
21	S21	30	30	10	30
22	S22	21.43	21.43	35.71	21.43
23	S23	30	30	30	10
24	S24	21.43	21.43	21.43	35.71

Result of Proximate analysis of raw protein sources

The result of proximate analysis of raw protein sources is shown in Table 3. The results of proximate analysis of defatted Soy flour, Kabuli Chickpea, Mushroom and Jackfruit, showing highest moisture content in Mushroom & Jackfruit, whereas lowest in Kabuli Chickpea and defatted Soy flour. Kabuli Chickpea found to contain high fat (8.6%) and Jackfruit shown low fat (0.6%).

High protein content observed in Defatted Soy flour (38.1 %) and Kabuli Chickpea (18.2 %), whereas Jackfruit and Mushroom shown low protein content due to their high moisture. Also because of high moisture content Mushroom and Jackfruit were showing less carbohydrate fiber as compared to Defatted soy flour and Kabuli chickpea. However all the considered vegetarian protein source were found to be the good sources of mineral as revealed in ash content.

Table 3 : Result of proximate analysis of raw protein sources

Parameters	Defatted Soy flour	Kabuli Chickpea	Mushroom	Jackfruit
Moisture (%)	5.87± 0.30	7.08 ±0.10	86.68± 4.4	79.29 ±4.7
Fat (%)	4.95± 0.20	8.60 ±1.00	1.56 ±0.6	0.6 ±0.1
Protein (%)	38.10 ±2.00	18.20 ±2.14	1.31 ±0.09	8.2 ±0.2
Ash (%)	3.48 ±0.10	8.83 ±0.05	4.75 ±1.8	1.5 ±0.5
Fibre (%)	3.97 ±0.10	6.56 ±1.66	5.2± 2.0	3.9 ±0.2
Carbohydrate	43.8 ±0.50	51.42 ±1.0	0.50± 0.7	11.8 ±3.8

*Above values are averages of three determinants ± standard deviation

Selection of Meat analogue formulations on the basis of texture profile analysis

The texture profile analysis results are shown in Table 4. It was found that most of the important textural properties like hardness,

chewiness, springiness, gumminess values of meat analogue formulations S1, S2, S4, S5, S6, S7, S8, S10, S11, S12, S15, S19, S20, S21, S22 and S23 were near and comparable to textural properties of

controlled sample (goat meat) (deformation at hardness: 8.52 mJ, adhesiveness: 2.18 mJ, cohesiveness: 2.14, springiness: 6.12 mm, gumminess: 212 g and chewiness: 8.92 mJ), the results showed a significant decrease in hardness (1.8mJ), springiness (1.82mm), chewiness(37mJ) and gumminess(0.7g) by increasing amount of defatted Soy flour (30%), Kabuli Chickpea flour(30%), Mushroom paste (30%) and decreasing amount of Jackfruit flour (10%) in the formulation, whereas increase in

deformation at hardness(18.3 mJ) by decreasing amount of defatted Soy flour (16.7%), Kabuli Chickpea flour(16.7%) and increasing amount of Mushroom paste (33.3%) and Jackfruit flour (33.3%) in the formulation, thus it is considered textured meat analogue formulations had meat like texture. Hence formulation S1, S2, S4, S5, S6, S7, S8, S10, S11, S12, S15, S19, S20, S21, S22 and S23 were selected for further screening on the basis of proximate evaluation.

Table 4 : Result of texture profile analysis of meat analogue formulations

Sample Code	Responses					
	Deformation at Hardness	Adhesiveness	Cohesiveness	Springiness	Gumminess	Chewiness
	mm	mJ		Mm	g	mJ
Controlled sample (S0)	8.52	2.18	2.14	6.12	212	8.92
S1	5.2	0.6	1.09	4.1	342	13.7
S2	5.2	0.7	0.52	3.02	142	4.2
S3	5.6	0.5	0.53	2.05	162	3.2
S4	3.9	0.5	0.84	2.84	202	5.6
S5	6.2	0.6	0.72	3.85	254	9.6
S6	2.8	0.2	0.55	3.23	100	3.2
S7	9.2	0.5	0.97	4.15	521	21.2
S8	3.9	0.6	0.87	3.81	209	7.8
S9	3.9	0.5	0.83	3.97	188	7.3
S10	4.8	0.9	1	4.12	340	13.7
S11	3.6	0.4	0.64	3.15	134	4.1
S12	4.7	0.6	0.63	2.09	174	3.6
S13	18.3	0.1	0.29	1.6	328	5.1
S14	5.8	0.8	0.76	4.08	268	10.7
S15	10.2	1.3	1.24	4.35	791	33.7
S16	4.5	0.6	0.41	1.98	101	2
S17	5.6	0.7	0.51	2.84	164	4.6
S18	4.5	0.7	0.4	2.12	96	2
S19	2.1	0.2	0.46	1.95	54	1
S20	2.6	0.4	0.39	1.97	56	1.1
S21	3.3	0.6	0.72	3.44	142	4.8
S22	3.1	0.5	0.51	2.9	87	2.5
S23	1.8	0.4	0.42	1.82	37	0.7
S24	3.1	0.6	0.88	4.06	161	6.4

*mJ: mega Joule, mm: millimeter, g: gram

Figure 1, 2, 3, 4, 5 and 6 is demonstrating the effect of composition of plant based meat sources (defatted Soy flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour) in the formulations on the various textural characteristics (hardness, adhesiveness, cohesiveness, springiness, gumminess and chewiness) of developed meat analogues. The Response surface design plot helped to

understand the interactions and influence of the composition of defatted Soya flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour on the various textural parameters (hardness, adhesiveness, cohesiveness, springiness, gumminess and chewiness) which formed the basis for screening the 24 samples to judge and select the said best 16 samples on the basis of various textural parameters.

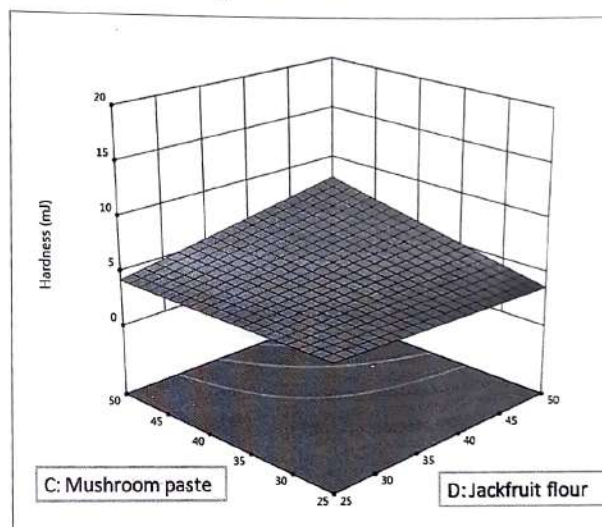
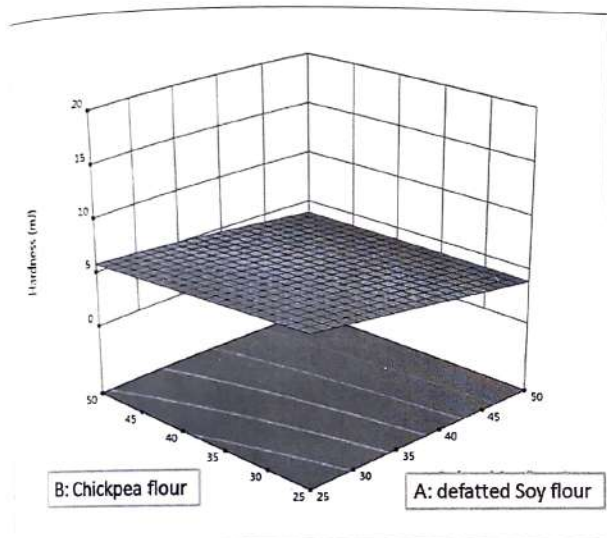


Figure 1: Response surface design plot depicting effect of Defatted Soy flour, Chickpea flour, Jackfruit flour and Mushroom paste on hardness.

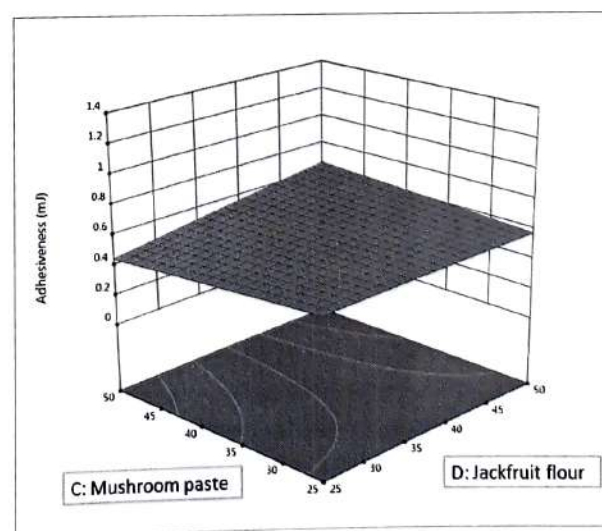
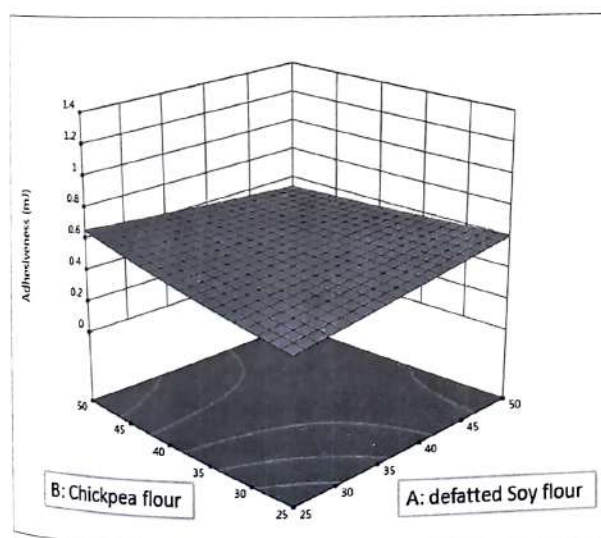


Figure 2: Response surface design plot depicting effect of Defatted Soy flour, Chickpea flour, Jackfruit flour and Mushroom paste on adhesiveness.

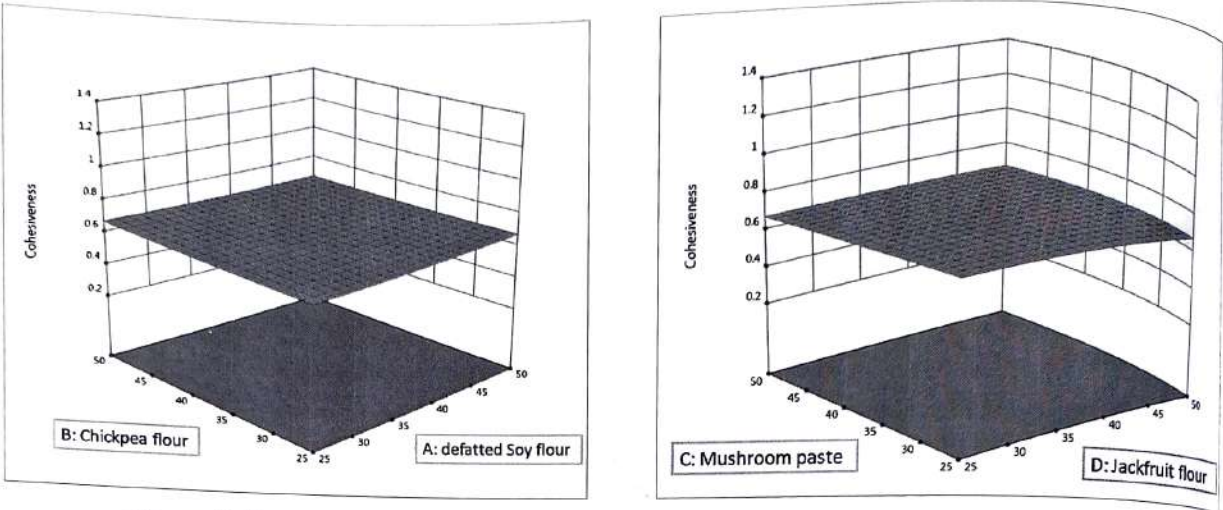


Figure 3: Response surface design plot depicting effect of Defatted Soy flour, Chickpea flour, Jackfruit flour and Mushroom paste on cohesiveness.

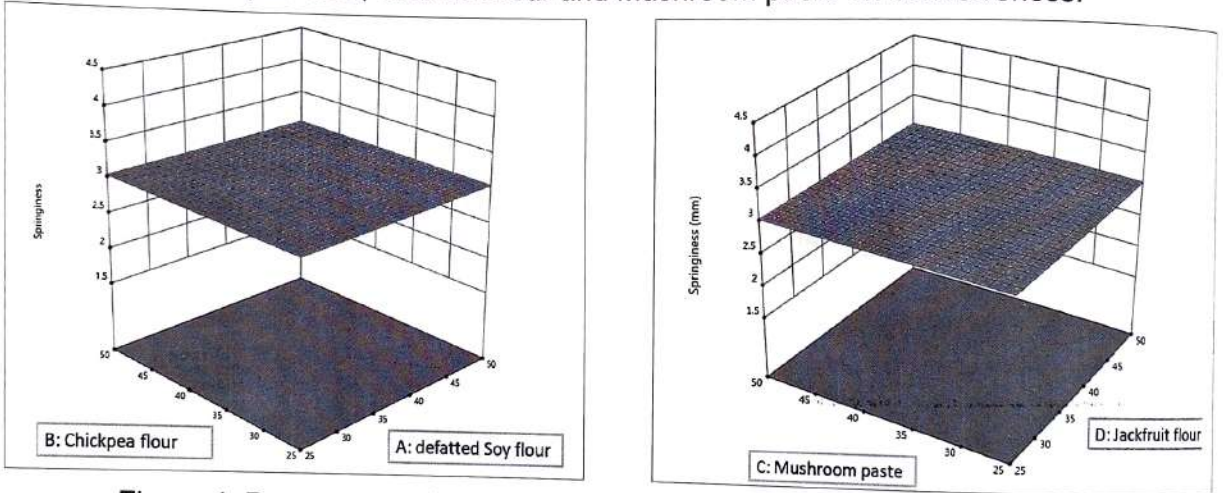


Figure 4: Response surface design plot depicting effect of Defatted Soy flour, Chickpea flour, Jackfruit flour and Mushroom paste on springiness.

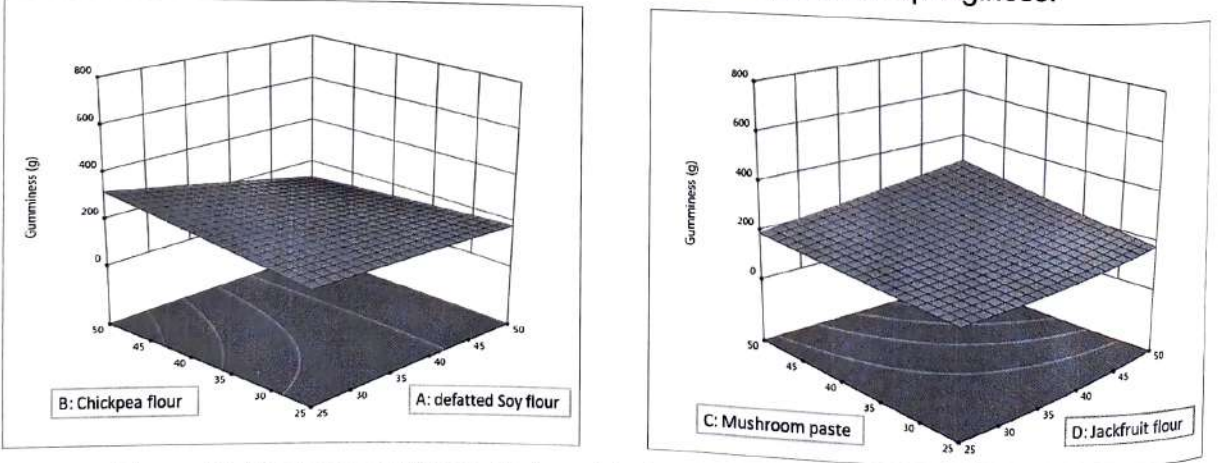


Figure 5: Response surface design plot depicting effect of Defatted Soy flour, Chickpea flour, Jackfruit flour and Mushroom paste on gumminess.

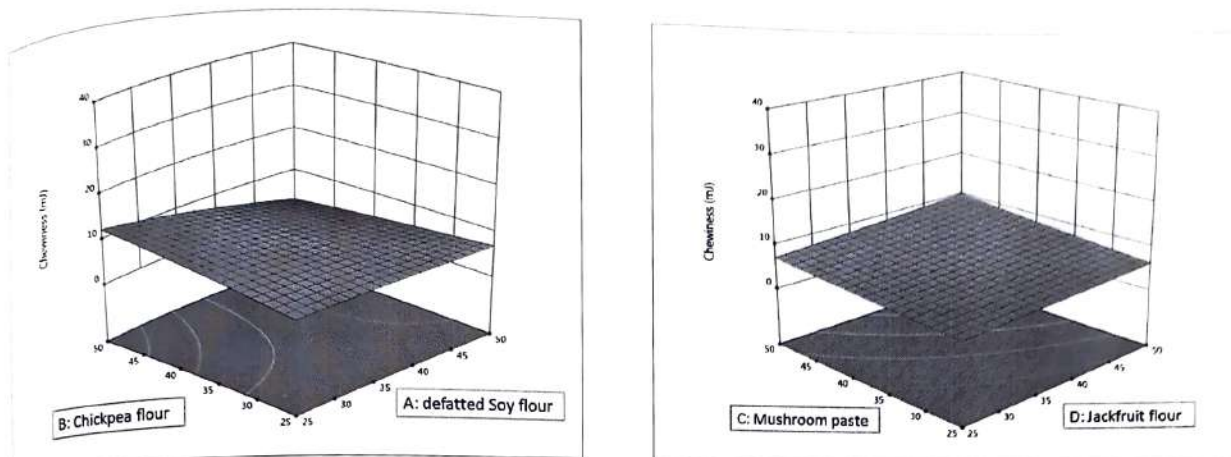


Figure 6: Response surface design plot depicting effect of Defatted Soy flour, Chickpea flour, Jackfruit flour and Mushroom paste on chewiness.

Selection of Meat analogue formulations on the basis of proximate composition

Table 5 is showing proximate analysis result of selected meat analogue formulations (S1, S2, S4, S5, S6, S7, S8, S10, S11, S12, S15, S19, S20, S21, S22, and S23). The result revealed that proximate composition of meat analogue formulations S2, S6, S8, S10, S12, S19, S20 and S22 were closer to proximate composition of controlled sample (goat meat) having protein content: 25.2 %, fiber content:

0.4 % and carbohydrate 23.1 %. As different formulations has variation in amount of protein sources (defatted Soy flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour) the protein content will vary accordingly, because only defatted Soy flour and Kabuli Chickpea flour contains high protein content than Mushroom paste and Jackfruit flour. Hence formulation S2, S6, S8, S10, S12, S19, S20 and S22 were selected for further screening on the basis of sensory evaluation.

Table 5 : Result of proximate analysis of meat analogue formulations

Sr. no.	Sample code	Moisture Content (%)	Protein content (%)	Fat Content (%)	Ash Content (%)	Fiber Content (%)	Carbohydrate (By Difference)
Controlled sample	S0	16.8	25.2	19.4	15.1	0.4	23.1
1	S1	31.27	16.42	0.89	4.09	0.4	46.93
2	S2	38.18	18.35	1.09	2.97	0.1	39.31
3	S4	47.34	16.36	0.29	2.87	0.3	32.84
4	S5	51.8	15.73	0.49	2.89	0.3	28.79
5	S6	51.34	17.72	2.23	2.98	0.4	25.33
6	S7	48.31	15.44	8.94	2.7	0.2	24.41
7	S8	38.31	18.38	2.37	2.9	0.3	37.74
8	S10	48.41	17.97	5.27	3.19	0.5	24.66
9	S11	45.43	15.58	3.87	2.98	1.3	30.84

Sr. no.	Sample code	Moisture Content (%)	Protein content (%)	Fat Content (%)	Ash Content (%)	Fiber Content (%)	Carbohydrate (By Difference)
10	S12	45.9	16.92	4.47	2.08	0.5	30.13
11	S15	51.39	15.35	5.25	5.68	0.5	21.83
12	S19	51.9	19.37	5.09	2.86	0.8	19.98
13	S20	46.51	17.18	4.27	4.17	0.5	27.37
14	S21	48.85	16.84	4.39	2.87	0.5	26.55
15	S22	49.85	18.43	2.48	2.98	0.4	25.86
16	S23	50.79	16.69	5.05	2.09	1	24.38

Figure 7 is demonstrating the effect of composition of plant based meat sources (defatted Soy flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour) in the formulations on the protein content of developed meat analogues. The Response surface design plot helped to understand the

interactions and influence of the composition of defatted Soya flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour on the protein content which formed the basis for screening the 16 samples to judge and select the said best 8 samples on the basis of protein content.

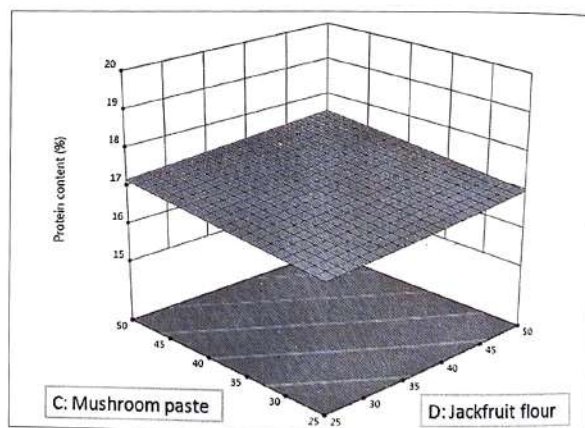
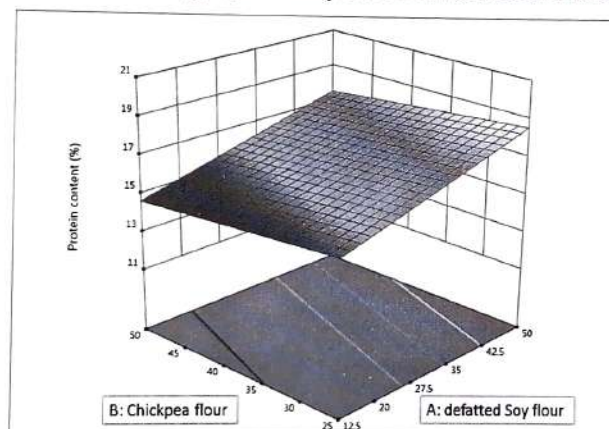


Figure 7: Response surface design plot depicting effect of Defatted Soy flour, Chickpea flour, Jackfruit flour and Mushroom paste on protein content.

Selection of meat analogue formulations on the basis of sensory analysis

Table 6 is representing the sensory evaluation result of selected meat analogue formulations (S2, S6, S8, S10, S12, S19, S20 and S22). It can be seen from the sensory result that the formulated samples S6, S10, S12, and S20 obtain low score as compared to another due to taste and mouthfeel

whereas S2, S8, S19 and S20 received satisfactory sensory score as this study was conducted only for optimization and development of meat analogue formulation, flavor and colour were not added in the formulation while texturization resulting low overall score and hence selected for further development as part of future research. On the basis of overall acceptability the ranking of selected samples were S19 > S2 > S8 > S22.

Table 6 : Result of sensory evaluation of selected meat analogue formulations

Sr.no.	Sample code	Colour	Taste	Mouthfeel	Texture	Overall Acceptability
1	S2	6 $\pm$ 0.47	6.3 $\pm$ 0.67	6.1 $\pm$ 0.57	6.4 $\pm$ 0.52	6.1 $\pm$ 0.32
2	S6	5.2 $\pm$ 0.63	4.4 $\pm$ 0.52	4.2 $\pm$ 0.42	5.2 $\pm$ 0.63	4.9 $\pm$ 0.57
3	S8	6.1 $\pm$ 0.57	6 $\pm$ 0.67	5.8 $\pm$ 0.92	6.3 $\pm$ 0.67	6.1 $\pm$ 0.57
4	S10	5 $\pm$ 0.67	4.6 $\pm$ 0.52	4.3 $\pm$ 0.48	5.2 $\pm$ 0.42	5 $\pm$ 0.00
5	S12	5.1 $\pm$ 0.74	4.7 $\pm$ 0.48	4.3 $\pm$ 0.48	5.3 $\pm$ 0.67	4.9 $\pm$ 0.32
6	S19	6 $\pm$ 0.00	6.9 $\pm$ 0.32	6.7 $\pm$ 0.48	7 $\pm$ 0.00	6.9 $\pm$ 0.32
7	S20	5.3 $\pm$ 0.82	4.5 $\pm$ 0.71	4.4 $\pm$ 0.52	5.5 $\pm$ 0.53	5.1 $\pm$ 0.57
8	S22	6 $\pm$ 0.00	5.8 $\pm$ 0.63	5.7 $\pm$ 0.67	6.2 $\pm$ 0.42	6 $\pm$ 0.00

*Above values are averages of ten determinants $\pm$ standard deviation

Figure 8 is demonstrating the effect of composition of plant based meat sources (defatted Soy flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour) in the formulations on the overall acceptability of developed meat analogues. The Response surface design plot helped to understand the

interactions and influence of the composition of defatted Soya flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour on the overall acceptability which formed the basis for screening the 8 samples to judge and select the said best 4 samples on the basis of overall acceptability.

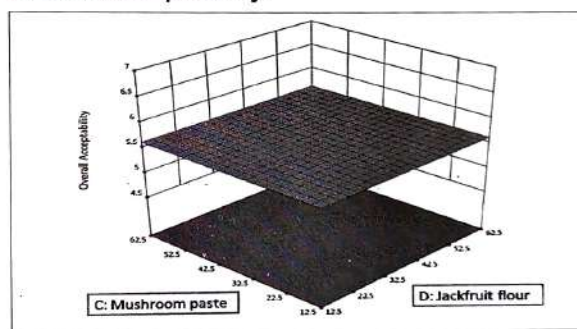
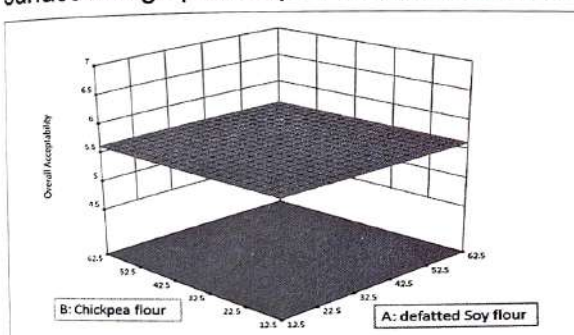


Figure 8 Response surface design plot depicting effect of Defatted Soy flour, Chickpea flour, Jackfruit flour and Mushroom paste on overall acceptability.

CONCLUSION

The present work concludes that the good quality of meat analogue can be prepared from combinations of defatted Soy flour, Kabuli Chickpea flour, Mushroom paste and Jackfruit flour without compromising the protein content, textural and sensory characters in comparison to the control meat (goat meat). Out of 24 formulations developed the meat analogue formulations S2 (defatted Soy flour 40 % + Kabuli chickpea flour 20 % + Mushroom paste 20 % + Jackfruit flour 20 %), S8 (defatted Soy flour 28.6 % +

Kabuli chickpea flour 28.6 % + Mushroom paste 28.6 % + Jackfruit flour 14.2 %), S19 (defatted Soy flour 30 % + Kabuli chickpea flour 10 % + Mushroom paste 30 % + Jackfruit flour 30 %), and S22 (defatted Soy flour 21.43 % + Kabuli chickpea flour 21.43 % + Mushroom paste 35.71 % + Jackfruit flour 21.43 %) were better in terms of protein content, texture and sensory. The preferred four meat analogue sample shown ranking as S19 > S2 > S8 > S22. The selected samples S19, S2, S8 and S22 can be the good source of textured protein and can replace meat.

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CONFLICT OF INTEREST

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this article.

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Evaluation of training program on reproductive health of adolescent girls

Pragaya Dashora¹, Simple Jain², Neeta Khandelwal³ and Renu⁴

^{1&4}Department of Human Development and Family Studies

^{2&3}Department of Extension Education and Communication Management

ASPEE College of Nutrition and Community Science, SDAU, Sardarkrushinagar

Email: pragayadashora@rediffmail.com

ABSTRACT

Reproductive health of adolescent is fundamental right. Due attention on the reproductive health of adolescent girls is essential to avoid future problems. Training is a good way to provide suitable information to adolescent girls to manage reproductive health hygienically with due dignity, boosts the confidence and share in decision making. With this view, a training program on the reproductive health of adolescent girls was organized and its evaluation was done. Study sample (respondents) consist of hundred adolescent girls of Sardarkrushinagar Vidyalaya. Pre-post research design and questionnaire technique was used for the study. Pre- test was done before the training, then two days training was organized and post test was taken to assess knowledge gain on various aspects of reproductive health. Descriptive statistics (frequency and percentage), correlation, and paired t-test were used for drawing the results. Findings indicate that post-test results were higher than the pre-test results in all aspects of reproductive health. Maximum knowledge gain was seen on the aspect of anatomy and functions of female reproductive system.

Keywords: Reproductive Health, Adolescents, Training program

INTRODUCTION

Adolescence is an important time for laying the foundations of good health. Adolescents form large section of the society. An adolescent is a person between 10 to 19 years of age and are in transitional phase of growth and development between childhood and adulthood (WHO, 2023). Rapid growth, restlessness, fatigue, hormonal changes, sexual maturity, vulnerability, experimentation, mood swings and inquisitiveness are chief characteristics of adolescence which have direct impact on the health of adolescents. Reproductive health is one of the basic rights of adolescents as they step into adulthood. But, unfortunately consciously or unconsciously it is violated. The issue of reproductive health is universally signified as it has fundamental

importance to socio-economic development of the community. The curiosity, inquisitiveness, knowledge and habits regarding reproductive health needs timely and correct guidance for shaping their future as well as making them responsible citizen of the nation. Knowledge about reproductive health also effectively deals with the episodes of teenage pregnancy, early puberty, decreasing age of sexual experimentation, high involvement in high risk sexual activities, Sexually Transmitted Infections (STIs) and diseases.

The usefulness of reproductive health is much more for adolescent girls as they bear the responsibility of future family extension. In spite of this, their participation in decisions over reproductive issues is meager. They are facing so many constraints in making informed life choices. Open or friendly

discussion on reproductive health is not so common in customary Indian social set up. Imparting right knowledge about this issue not only helps them to effectively deal with its ailing effects but also motivate girls to manage reproductive health hygienically with due dignity. Training is an effective way to spread knowledge as it gives them opportunity to get direct and reliable information from authentic sources. Training also helps to improve behavior, performance and decision making. As per George, (1999) planned teaching programme is an effective approach to improve the knowledge among female about menstrual hygiene. Mann (2010) studied the effectiveness of planned teaching programme on puberty and confirmed eighty per cent (80.71%) improvement among knowledge level of adolescent girls. Similarly, Jyothi and Kamalam (2005) also indicated significant improvements in the knowledge level of adolescent girls after administering planned teaching programme on reproductive health. Identical observations were made by Jahanfar (2009) who reported that instructional material significantly improves the knowledge, attitude and practice of adolescents in relation to the reproductive health.

In view of this, the research study was taken with the aim to conduct the training programme on the reproductive health of the adolescent girls. Moreover, the training was evaluated on the knowledge gain of adolescent girls regarding reproductive health. The association between knowledge gain and socio personal characteristics of adolescent girls was also explored.

METHODOLOGY

The Sardarkrushinagar Vidyalaya was selected for the purpose of the study. One hundred girl students of IX to XII standard were selected as respondents for the study.

Pre-post test research design was used for the study. Pre-test was conducted prior to organization of training on reproductive health. Two days training was organized for the adolescence, which includes reproductive health, family planning and female reproductive system. The lecture method was used to enhance knowledge of adolescence regarding the reproductive health and post test was also done to assess the knowledge gain. Questionnaire technique was used to collect the data. Descriptive statistics (frequency and percentage), correlation, and paired t-test were used for analyzing the data.

RESULTS AND DISCUSSION

The study results are presented into three sections

I Socio-demographic details of respondents

Socio-personal details are very significant in social research area and that has been presented in Table 1. It includes information about age, class, category, family type, number of family members, education and occupation of mother and father, monthly family income, age at menarche or onset of menstrual cycle, cycle of menstrual and mass media exposure.

Age wise distribution of respondents indicates that more than half (57.0%) of the respondents were in the age of 14-15 years. Nearly forty (36.0%) percent of respondents were studying in class IX which was followed by class X (26.0%). Categories wise distribution shows that maximum number (43.0%) of respondents were from general category. Sixty five (65.0%) percent respondents were from joint family. More than sixty (61.0%) percent respondents had six to ten family members. More than half (53.0%) of the respondents' mothers were illiterate. With regard to maternal occupation it was found that eighty eight (88.0%) percent

were homemakers. Father of little more than half (53.0%) of the respondents were educated up to primary level. Mainly fathers of respondents were engaged in government jobs (30.0%) and doing business (40.0%). Most of the respondents (34.0%) had family income between Rs. 10,000 to 20,000. Sixty three (63.0%) percent respondents reported fourteen years (14 years) of age at the time of menarche (beginning of menstrual cycle). More than half (57.0%) of the respondents mentioned that their menstrual cycle is irregular. About media possession it was found that maximum respondents had television (75.0%) and mobile phone (51.0%). With regard to socio personal characteristics it can be summed up that most of the

respondents were in 14-15 years of age, studying in class IX, from general category, belong to joint family, having six to ten family members, had family income of rupees 10,000 to 20,000 monthly, initiated menstrual cycle but irregular, had television and mobile phones. Maternal as well as paternal education was low. The respondents indicated that they were having television and mobile but less exposed to social media platforms as these were jointly possessed and used by whole family. According to Saha *et al* (2022). Adolescents who were exposed to social media platforms were likely to have more Sexual and reproductive health (SRH) knowledge compared to those who were not.

Table 1 : Distribution of the respondents according to socio-personal variables (n = 100)

Sr. No.	Demographic variables	Categories	Frequency (f) and Percentage (%)
1.	Age (in years)	14 -15 years	57 (57.0%)
		16 - 18 years	43 (43.0%)
		IX	36 (36.0%)
		X	26 (26.0%)
2.	Class	XI	19 (19.0%)
		XII	19 (19.0%)
		Schedule Tribe	16 (16.0%)
		Schedule Caste	11 (11.0%)
	Category	Other Backward Caste	30 (30.0%)
		General	43 (43.0%)
		Nuclear	35 (35.0%)
		Joint	65 (65.0%)
4.	Family Type	Upto 5 members	35 (35.0%)
		6 to 10 members	61 (61.0%)
		11 and more	04 (04.0%)
		Illiterate	53 (53.0%)
5.	No. of family members	Up to Primary	33 (33.0%)
		Secondary	11 (11.0%)
		Sr. Secondary	03 (03.0%)
		Graduate and above	0 (0.0%)
6.	Mother's educational qualification	Housewife	88 (88.0%)

	Labor	05 (05.0%)
	Private employee	0 (0.0%)
7. Mother's Occupation	Government employee	05 (05.0%)
	Business	0 (0.0%)
	Farming only	02 (2.0%)
	Illiterate	09 (9.0%)
8. Father's educational qualification	Up to Primary	53 (53.0%)
	Secondary	20 (20.0%)
	Senior secondary	09 (9.0%)
	Graduate and Above	09 (9.0%)
9. Father's Occupation	Labor	18 (18.0%)
	Private employee	12 (12.0%)
	Government employee	30 (30.0%)
	Business	40 (40.0%)
	Farming only	0 (0.0%)
10. Monthly Family Income (in Rs.)	Below 10,000	21 (21.0%)
	10,000 to 20,000	34 (34.0%)
	20,000 to 25,000	22 (22.0%)
	25,000 to 30,000	09 (9.0%)
	30,000 and above	14 (14.0%)
11. Age at the time of menarche	12 Years	18 (18.0%)
	14 years	63 (63.0%)
	15 Years	08 (8.0%)
	Not replied	11 (11.0%)
12. Cycle of menstruation	Regular	43 (43.0%)
	Irregular	57 (57.0%)
13. Media possession (Based on multiple response)	TV	74 (74.0%)
	Computer	12 (12.0%)
	Laptop	06 (6.0%)
	Landline	05 (5.0%)
	Mobile	51 (51.0%)
	Internet	11 (11.0%)
	News paper	05 (5.0%)
	Any other	06 (6.0%)

II Knowledge gain through training regarding various aspects of reproductive health

This section presents findings about knowledge gain through training regarding various aspects of reproductive health. It is presented under following subheads:

2.1 Knowledge gain about concept and other aspects of Adolescents

Table 2 shows the description about pre-post test knowledge scores regarding adolescence and its various aspects. It is clear from the Table-2 that mean value for meaning of adolescents was 2.41 for pre-test

and 2.80 for post test, with 't' value 4.65 which shows highly significant difference. For changes during adolescence mean value for pre-test was 4.64 while for post -test 6.72 with 't' value 6.23 that shows highly significant knowledge improvement. The mean value for importance as an adolescent for pre-test and

post-test were 0.83 and 0.92 respectively with 't' value 2.80. It indicates significant differences. With regard to problems of adolescents mean scores of pre-test and post-test were 1.14 and 1.94 respectively with 't' value 6.87. It shows significant differences.

Table: 2 Knowledge gain among adolescent girls regarding adolescence (n=100)

Sr. No.	Aspects	Test	Mean Value	Mean Value Difference	Standard Error of Mean Difference	't' Value
1.	Meaning of adolescents	Pre -Test	2.41	0.39	0.08	4.65**
		Post -Test	2.80			
2.	Changes during adolescence	Pre -Test	4.64	2.08	0.33	6.23**
		Post -Test	6.72			
3.	Importance as an adolescent	Pre -Test	0.83	0.09	0.03	2.80**
		Post -Test	0.92			
4.	Problems of Adolescents	Pre -Test	1.14	0.80	0.12	6.87**
		Post -Test	1.94			
	Overall	Pre -Test	9.02	3.36	0.42	8.10**
		Post -Test	12.38			

Table: 3 Knowledge gain regarding information and scenario of reproductive health (n=100)

Sr. No.	Aspects	Test	Mean Value	Mean Value Difference	Standard Error of Mean Difference	't' Value
1.	Concept of RH	Pre-test	0.62	0.27	0.05	6.05**
		Post-test	0.89			
2.	Sources of information	Pre-test	0.79	0.27	0.06	4.77**
		Post-test	1.06			
3.	Issues related to RH	Pre-test	1.81	0.76	0.16	4.78**
		Post-test	2.57			
4.	Approaches for better RH	Pre-test	1.45	0.51	0.17	3.07**
		Post-test	1.96			
	Overall	Pre-test	4.67	1.81	0.30	6.06**
		Post-test	6.48			

**Significant at 1 per cent level

2.2 Knowledge gain about information and scenario of reproductive health

The pre-post test scores regarding

information and scenario of reproductive health have been presented in Table 3. About concept of reproductive health post-test

(0.89) scores was significantly higher than pre-test (0.62) with 't' value 6.05. The mean value of issues related to reproductive health was 0.79 for pre-test and 1.06 for post-test with 't' value 4.77 which confirms the significant improvement in knowledge. Regarding issues related to reproductive health mean scores 1.81 and 2.57 were found for pre and post test respectively with 't' value 4.78. Similarly, respondents had significant improvement in knowledge regarding approaches for better reproductive health as post-test (1.96) scores were higher than pre-test (1.45) with 't' value 3.07.

Overall mean value for pre-test was 4.67 and post-test was 6.48 with 't' value 6.06 that shows highly significant improvement in knowledge of respondents about information and scenario of RH.

Poor knowledge scores in pre-test about information and scenario of RH indicates that

respondents were less informed about this important issue. As Morris and Rushwan (2015) revealed that adolescent sexual and reproductive health (ASRH) has been overlooked historically despite the high risks that countries face for its neglect. Some of the challenges faced by adolescents across the world include early pregnancy and parenthood, difficulties accessing contraception and safe abortion, and high rates of HIV and sexually transmitted infections. Various political, economic, and socio-cultural factors restrict the delivery of information and services; healthcare workers often act as a barrier to care by failing to provide young people with supportive, nonjudgmental, youth-appropriate services.

2.3 Knowledge gain about early marriage

The knowledge gain about early marriage on the basis of pre-test and post-test are presented in Table 4.

Table: 4 Knowledge gain about early marriage

(n=100)

Sr. No.	Aspects	Test	Mean Value	Mean Value Difference	Standard Error of Mean Difference	't' Value
1.	Legal age of marriage	Pre-test	0.86	0.04	0.02	1.65**
		Post-test	0.90			
2.	Prevalence of early marriage	Pre-test	1.34	0.17	0.07	2.55*
		Post-test	1.51			
3.	Problems of early marriage	Pre-test	0.93	0.43	0.11	4.03**
		Post-test	1.36			
	Overall	Pre-test	3.30	0.30	0.15	2.04*
		Post-test	3.60			

**Significant at 1 per cent level

* Significant at 5 per cent level

Table 4 shows knowledge scores about early marriage and its different aspects. Regarding legal age of marriage pre-test (0.86) and post test (0.90) scores varied significantly with 't' value 1.65. For prevalence of early marriage 1.34 and 1.51 were pre-test and post-test (1.34) score respectively with 't' value 2.55.

Further, respondents had mean value regarding problems of early marriage, the pre-test (0.93) and post- test (1.36) with 't' value 4.03 showed highly significant difference.

Overall, it was found that knowledge gain for different aspects of early marriage i.e. legal

age of marriage, prevalence and problems of early marriages was highly significant as pre-test (3.30) and post-test (3.60) scores varied significantly. Young women who had married at age 18 or older were more likely than those who had married before age 18 to have been involved in planning their marriage, to reject wife beating, to have used contraceptives to delay their first pregnancy and to have had their first birth in a health facility. They were less likely than women who had married early

to have experienced physical violence or sexual violence in their marriage or to have had a miscarriage or still birth (Santhya *et al.* 2010).

2.4 Knowledge gain about family planning

The knowledge of adolescent girls about family planning and its different aspects are presented in Table 5. It covers knowledge about use of family planning measures and methods of family planning.

Table : 5 Knowledge gain about family planning (n=100)

Sr. No.	Aspects	Test	Mean Value	Mean Value Difference	Standard Error of Mean Difference	't' Value
1.	Knowledge regarding Use of FP measures	Pre-test	0.28	0.29	0.08	3.84**
		Post-test	0.57			
2.	Methods of FP	Pre-test	1.73	0.63	0.24	2.62**
		Post-test	2.36			
Overall		Pre-test	2.01	0.92	0.26	3.54**
		Post-test	2.93			

**Significant at 1 per cent level

It is evident from Table 5 that mean value of knowledge regarding use of family planning measures was 0.28 for pre-test and 0.57 for post-test, with 't' value 3.84 which shows highly significant difference. For methods of family planning pre-test (1.73) and post-test (2.36) scores varied significantly with 't' value 2.62.

The mean value of pre-test and post-test in case of overall were 2.01 and 2.93 respectively with 't' value 3.54 which indicates highly significant knowledge gain.

2.5 Knowledge gain about anatomy and functions of female reproductive system

Knowledge gain for anatomy and functions of female reproductive system (FRS) are presented in Table 6. For internal anatomy the mean value for pre-test (3.41) was very less as compared to post-test (12.44) value with 't' value 9.30. About functions of female reproductive system, the difference between pre-test (3.17) and post-test (4.44) scores

with 't' value 4.68 indicates significant knowledge gain due to training. Highest knowledge gain was for internal anatomy which was followed by menarche and menopause. For external anatomy of female reproductive system (FRS) and consequences of improper care of FRS the difference was not significant.

When looked overall (about anatomy and functions of female reproductive system), highly significant variation was noticed between pre-test (16.15) and post-test (29.49) with 't' value 11.05. It shows that respondents were not having proper knowledge about anatomy and functions of female reproductive system and they get benefited through the training. Due to lack of knowledge about reproductive system adolescent girls were unaware about menstrual process and menstrual hygiene (Parida *et al.*; 2021) that increases teenage pregnancy, unsafe abortions, RTIs, STIs, and unsafe sex practices.

Table : 6 Knowledge gain about anatomy and functions of female reproductive system (n=100)

Sr. No.	Aspects	Test	Mean Value	Mean Value Difference	Standard Error of Mean Difference	't' Value
1.	Internal Anatomy of FRS	Pre-test	3.41	9.03	0.97	9.30**
		Post-test	12.44			
2.	External Anatomy of FRS	Pre-test	1.02	0.33	0.19	1.75NS
		Post-test	1.35			
3.	Functions of FRS	Pre-test	3.17	1.27	.27	4.68**
		Post-test	4.44			
4.	Menstruation	Pre-test	6.94	1.87	.50	3.71**
		Post-test	8.81			
5.	Menarche and menopause	Pre-test	0.84	0.50	.09	5.40**
		Post-test	1.34			
6.	Consequences of Improper care of FRS	Pre-test	0.77	0.34	.18	1.93NS
		Post-test	1.11			
	Overall	Pre-test	16.15	13.34	1.21	11.05**
		Post-test	29.49			

**Significant at 1 per cent level.

2.6 Overall Knowledge gain regarding reproductive health of adolescent girls

Table 7 shows knowledge gain regarding overall reproductive health of adolescent girls. The mean values of post-test (12.48, 6.48, 3.60, 2.93 and 29.49) for all aspects of reproductive health were higher than pre-test scores (9.02, 4.67, 3.30, 2.01 and 16.15).

Maximum knowledge (13.34%) was gained in the aspect of anatomy and functions of female reproductive system (FRS) with Rank I. It was followed by knowledge gained about adolescence (Rank II) and information & scenario for reproductive health (Rank III). Knowledge gain about family planning was at Rank IV. Least knowledge was gained in the aspect of early marriage (Rank V).

Table: 7 Knowledge gain about overall reproductive health (n=100)

Sr. No.	Aspects	Test	Mean Value	Mean Value Difference	Standard Error of Mean Difference	't' Value	Rank
1.	Knowledge among adolescent girls regarding adolescence	Pre-test	9.02	3.36	0.42	8.10**	II
		Post-test	12.38				
2.	Information and scenario for reproductive health	Pre-test	4.67	1.81	0.30	6.06**	III
		Post-test	6.48				

Sr. No.	Aspects	Test	Mean Value	Mean Value Difference	Standard Error of Mean Difference	't' Value	Rank
3.	Early marriage	Pre-test	3.30	0.30	0.15	2.04*	V
		Post-test	3.60				
4.	Family Planning	Pre-test	2.01	0.92	0.26	3.54**	IV
		Post-test	2.93				
5.	Anatomy and functions of female reproductive system (FRS)	Pre-test	16.15	13.34	1.21	11.05*	I
		Post-test	29.49				
	Overall	Pre-test	35.15	19.73	1.74	11.34**	
		Post-test	54.88				

Highest gain in the anatomy and functions of female reproductive system might be due to their curiosity and sensitivity to learn and know about self-body. Their concern about structure of reproductive system and its functioning might encouraged them to grasp the higher knowledge through training programme. The knowledge about female reproductive structure and functions might be higher as the open discussion about such issues is not done in traditional family set up. Least improvement in knowledge regarding early marriage might be due to the fact that such marriages are not so common now a day due to legal compulsions. Moreover, it still persists behind the seen. Adolescent girls also hesitated to inform the correct picture because of fear of law and unacceptable practices of their society which is not even appreciated by others.

Results are in support of Vincet and Krishnakumar (2022) who highlighted that sexuality education programs positively influences adolescents to develop their knowledge, attitude, and behavior related to sexual and reproductive health and emphasized that adolescents must be informed about pregnancy prevention, Sexually Transmitted Infections (STIs), sexual hygiene, and reproductive health for better future.

III Association between the socio personal variables and knowledge gain about reproductive health (RH)

Table 8 present the result about the association of socio personal variables and knowledge gain regarding reproductive health.

Table : 8 Association between the socio personal variables and knowledge gain about reproductive health (RH)

(n=100)

S. No.	Socio personal variables	"r" value Knowledge gain
1.	Age	.024
2.	Class	.011
3.	Caste	-.244*
4.	Family Type	-.074
5.	Maternal Education	.018
6.	Paternal Education	.045
7.	Maternal Occupation	-.097
8.	Paternal Occupation	.111
9.	Family Income	-.028
10.	Media Possession	-.084
11.	Regularity of periods	-.007
12.	Menarche age	.017

* Correlation is significant at the 0.05 level
Association between different socio personal variables (age, class, caste, family type,

maternal education, paternal education, maternal occupation, paternal occupation, family income, media possession, regularity of periods and age at menarche) and gain in knowledge regarding reproductive health are studied and findings are presented in Table 8.

Knowledge gain was significantly associated with caste (-0.244). Positive but non-significant association of knowledge gain was noticed with age (0.024), class (0.011), maternal education (0.018), paternal education (0.111) and age at menarche (0.017) whereas non-significant negative association was noticed for family type (-0.074), maternal occupation (-0.097), family income (0.028), media possession (-0.084) and regularity of periods (-0.007). Sexual and reproductive health is influenced by socio-personal factors like place of residence, education level and high wealth index and exposure to social media platforms.

The reason might be low parental education, rural residence, low exposure to online as well as offline knowledge sources, social taboos etc. Moreover, the reproductive health of adolescents is overlooked since long. Adequate and appropriate information about this important issue is not provided to them due to social, cultural, political and other reasons. This leads to early pregnancies, untimely parenthood, poor knowledge of contraception and abortion methods, high rate of HIV and sexually transmitted diseases, involvement of youth in wrong practices, premarital unprotected sex. Same were the observations of Morris and Rushwan, 2015; Kyilleh *et al*, 2018 as well as Parida *et al*, 2021. Training program is a perfect way to improve the knowledge of adolescents about reproductive health aptly to avoid future ill consequences.

CONCLUSION

The study concludes that the training program significantly improves adolescent girls' knowledge about reproductive health, decision-making and better reproductive health outcomes. Maximum knowledge was gained in the aspect of anatomy and functions of female reproductive system (FRS). Training is a good way to satisfy the inquisitiveness of adolescent girls and it also prepares them for further challenges. Trainings can be a source of information empowerment especially for rural girls who lack the information about reproductive health.

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Almond shell incorporated fibre rich biscuits

Snehal Kale¹ and Vishal Parate²

Department of Food Technology, UICT, KBCNMU, Jalgaon
Email : kaleneha34@gmail.com and vishal_parate@yahoo.com

ABSTRACT

The essence of the current study lies in the fact that almond shells are a cheap, widely accessible source of dietary fibre and bioactive compounds that have several positive health effects. The objective of the present study was to develop fibre-rich biscuits by incorporating almond shell powder in control biscuits formulation. The control biscuits were prepared in lab by using refined wheat flour, fat, water sugar, and sodium bicarbonate along with other ingredients. The almond shells were separated from almond fruits then defatted, dried and powdered for incorporation in control biscuits at various levels of 5%, 10%, 15%, 20%, 25%, and 30% by replacing refined wheat flour. The prepared almond shell powder was showing 45.2 % crude fibre. The prepared almond shell powder incorporated biscuits and control biscuits were analysed for different Physico-chemical and sensory parameters. The result revealed that as the level of incorporation of almond shell powder increased, the diameter, thickness, weight and volume of biscuit also increased and the density, spread ratio and spread factor decreased as compared to the control biscuit. The incorporation of almond shell powder found to elevate the crude fibre and ash of the control biscuits. The sensory evaluation of almond shell powder-fortified biscuits was done by 10 semi-trained panel members using 9 point hedonic scale. After control, the biscuits incorporated with 20% level of almond shell powder receive highest overall acceptability. The biscuit incorporated with 20 % almond shell powder found to contain 14.51 % fibre. The study thus concludes that it is possible to prepare acceptable quality fibre rich biscuits by incorporating maximum 20 % almond shell powder in the formulation of control biscuits.

Keywords : Almond shells, Fibres, Biscuits, Physico- Chemical Analysis

INTRODUCTION

The worldwide production of Almond in previous year 2021-22 was 1.68 Metric Tons [Shahbandeh M, 2022]. The major waste arising from almond fruit is almond shell. Almond shell contains a high amount of dietary fibres in the form of cellulose, hemicelluloses, and lignin (Ramos M, *et al*, and Barber T, *et al*, 2020). Recently Kalhaoui *et al*, 2022, prepared bread by incorporating 8% of almond shell powder into wheat flour and found that the prepared bread was acceptable, good in taste, safe for consumption and the good source of fibre at 26.66%. The intake of dietary fibres shows

good health benefits in terms of microbial gut flora, colonic health, cardio-vascular diseases, and reducing severity of type-2 diabetes [Stephen, A, *et al*, 2017]. There should be daily intake of dietary fibre is 25–35 g/day (Prgomet, *et al*, 2017).

1.1 Almond Shell as a Source of Nutrients and Bioactive Compounds

The dried almond shell contains the highest amount of fibre that 25% along with a high sugar content from 18 -30% and Protein content around 8 % (Li X, *et al*, 2018). Mostly almond shells are used as livestock feed. Almond shells are found to be a good source of bioactive compounds and natural

antioxidants such as flavonol glycosides, phenolic acids (caffeine, ferulic, p-coumaric, and synaptic acids), triterpenoids (betulinic, urosolic, and oleanolic acids), catechin, vanillic acid, protocatechuic acid, and other polyphenolic compounds (Barral-Martinez, M, 2021, Wijeratne, S, *et al*, 2006 and Garcia-Perez, P, *et al*, 2021). The total polyphenolic content is comprised of between 35.9 and 166.7 mg GAE/g extract. The addition of almond shell powder reduces the risk of colon cancer in rats, reduces LDL cholesterol levels in humans, reduces DNA scission and metal ion chelation activities, and increases high-density lipoprotein cholesterol levels (Wijeratne, S, 2006, Barral-Martinez, M, 2021 and Manley, D. 2011).

1.2 Fibre-Rich Biscuits

The word biscuit was derived from the Latin word *twice biscotus*, which means "twice cooked bread. Initially, the biscuits were used on long maritime journeys and were made up of only flour, water, and sugar (Parate, V, *et al*, 2019). Biscuits are loved by all aged group people because it is ready to eat, good in test and available in minimum price (Ranganna S, 1986). Now a day, the biscuits are made up of various ingredients such as refined wheat flour, fat, sugar, flavour, salt, liquid glucose, milk, chocolates, fruit, nuts, etc. as per the customer's requirement. Almond shells are a cheaply available source of Dietary fibres along with natural antioxidant and bio- active compounds which possess several health benefits. In the market survey it was found that the peoples are purchasing fibre rich biscuits of different brands, like oat bran, rice bran, wheat bran and corn bran, etc., to fulfil the requirement of Dietary fibres. Almond shells are cheap and easily available source of dietary

fibres hence the aim of the said work was decided to develop fibre rich almond shell biscuit to minimize the bio degradable waste and to introduce new fibre rich biscuit in the market to satisfy the nutrient requirement. The addition of almond shell fibres in biscuits may help to treat several health issues like laxation, blood pressure, appendix, obesity and diabetes (Pawde S, *et al*, 2020 and J. W. Anderson, *et. al.*, 2009). The aim of the present work was to develop fibre-rich biscuits by incorporating almond shell powder in the formulation of control biscuits.

MATERIALS AND METHODS

The different raw materials and chemicals required for the preparation of almond shell biscuits are Almond Shells (Gurbandi Hard Shell Almonds, origin – Jammu and Kashmir, India), Refined Wheat Flour (Samrat), Liquid Glucose (Bake King), Inverted Sugar Syrup (Purix), Ammonium Bicarbonate (Bake King), sugar (Madhur), Distilled water, baking powder (Purix), skimmed milk powder (Nestle), fat (Amul Butter), salt (Tata), and flavour (Vanilla-Flying Bird). All the required materials were purchased from the local market in Jalgaon.

2.1 Preparation of Defatted Almond Shell Powder

The almond shells were defatted using petroleum ether in Soxhlet assembly (Remi- Soxhlet Assembly) for 16 to 18 hours. The defatted almond shell sample was collected and kept in a Hot air oven (Lab Hosp- Hot Air Oven) at 105 °C for 4 hours for the purpose of drying. The defatted, dried sample of almond shells was ground in a home grinder (Jyoti Mixer) and sieved with a 105-micron sieve to obtain a uniform particle size. The prepared almond shell powder was stored in HDPE bags for further use.

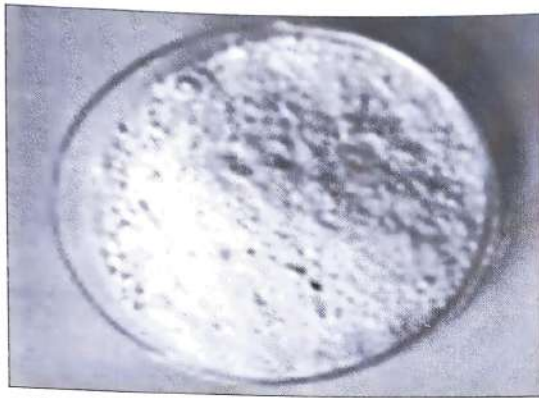


Fig 1: Almond Shell Powder

Figure 1, shows the image of prepared Almond Shell Powder at laboratory level which was light brown in colour.

2.2. Preparation of the Control Almond Shell Biscuit

The control biscuits were prepared in the laboratory using refined wheat flour. The ingredients and processing parameters used for the preparation of control biscuits are given in Tables 1. All the processing parameters were set by trial-and-error method and finalized as Pre-mixing time: 10 min, Finalize Mixing time: 10 min, Holding time: 10 min, Forming Dough Weight was 9.5 gm, Forming Dough Diameter was 55 mm, Forming Dough Thickness: 5.6 mm, Baking Temperature: 180°C and Baking Time: 13 min.

Table 1: Formulation of Control Biscuits

Ingredients	Quantity
Refined wheat flour (gm)	200
Fat (gm)	80
Sugar (gm)	120
Water (ml)	48
Invert Sugar Syrup (gm)	20
Flavour (ml)	0.8
Ammonium Bicarbonate (gm)	0.2
Salt (gm)	1
Liquid Glucose (gm)	20
Skimmed Milk Powder (gm)	16
Sodium Bicarbonate (gm)	6



Figure 2: Control Biscuits

The image of prepared Control Biscuit is shown in Figure 2. The control biscuit was made by using refined wheat flour that is without incorporating almond shell powder.

2.3. Preparation of Almond Shell Fortified Biscuits

In the preparation of almond shell fortified biscuit, the prepared almond shell powder was added in the formulation of control biscuits to the level of 5%, 10%, 15%, 20%, 25%, and 30% by replacing maida.

There was no difference in the amount of other ingredients added to the formulation and process parameters compared to the control biscuit (almond shell). Since the surface of the biscuits with almond fibre in them was found to be drier than that of the control biscuits, hence the additional water was added in the formulations of almond shell incorporated biscuits. The amount of water in the control biscuit formulation was steadily increased as the level of fibre incorporation raised. The fortified biscuits then underwent physical, chemical, and sensory tests.

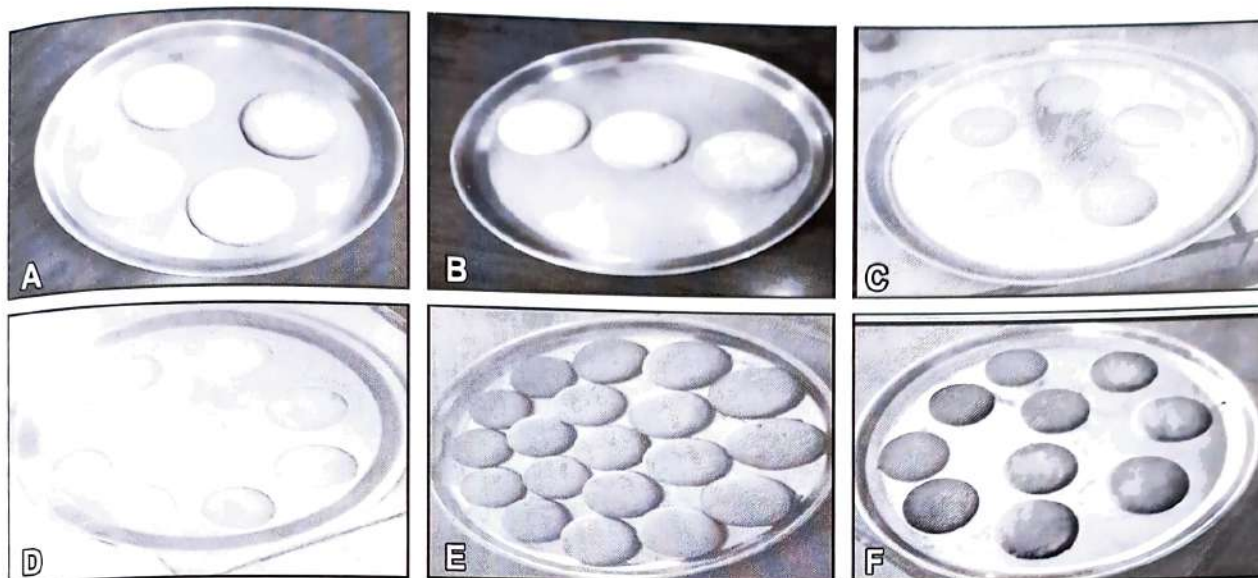


Figure 3: Almond Shell Powder Incorporated Biscuits

Figure 3, illustrates the biscuits incorporated with various levels of almond shell powder. Image A, B, C, D, E and F is representing biscuits incorporated with almond shell powder to the level of 5%, 10 %, 15 %, 20 %, 25 % and 30 % respectively

2.4. Evaluation of Prepared Biscuits

Using the standard testing protocols outlined in Ranganna 1986, the prepared almond shell biscuits were examined for various chemical parameters like, Moisture Content (Lap Hosp- Hot Air Oven), Ash (Muffle Furnace- Sisco India 220- 230 Volts), Fibre (Pelican Crude Fibre Analyzer FES04AS), Fat (Remi- Soxhlet Assembly), Protein (Pelican Protein Analyzer- KES04LVA), Energy, and Carbohydrates (By Difference Method). The sensory evaluation of prepared control and almond shell-incorporated biscuits was done by 10 semi-trained panel members. The analysis was done by judging taste, texture, colour, aroma, and overall acceptability, and ratings were given from 1 to 9 on the basis the hedonic scale.

2.5. Physical Analysis of Almond Shell Biscuits

According to the procedures outlined by Parate *et al.* (2016), the physical analysis of the biscuits was carried out based on their weight, thickness, diameter, spread ratio, volume, density, etc.

2.5.1 Weight (gm):

The weight of 5 Biscuits were taken in grams and mean was calculated along with standard deviations. The Mettler Toledo (ME204/A04) weighing balance was used for weighing purpose.

2.5.2 Thickness and Diameter (mm)

The Vernier calliper (Aero Space) was used for measuring the thickness and diameter of prepared biscuits at laboratory level.

2.5.3 Spread Ratio (%)

The spread ratio of biscuits was calculated by dividing diameter of biscuit by the thickness of biscuit.

2.5.4 Spread Factor (%)

The spread factor of prepared biscuit was calculated as percentage with spread ratio of biscuit divided by the spread ration of control biscuit.

2.5.5 Volume (cm³)

The volume of biscuit was determined by following given formula:

$$\text{Volume of Biscuit} = \frac{Td^2\pi}{4}$$

Where,

d= Diameter of biscuit, T = Thickness of biscuit

2.5.6 Density (g/cm³):

Density was calculated as the ratio of weight of biscuit to the volume of biscuit

RESULTS AND DISCUSSIONS

Table 2, displaying the powdered almond shell analytical results. The study of almond shell powder revealed that it included 5.02% of protein, 0.55% of pectin, 32.44% of hemicelluloses, 4.24% of lignin, and 28.22% of cellulose. The high amount of dietary fibres in almond shell powder was demonstrated by the analytical findings; as a result, it was appropriate to add it to the control biscuit to boost the level of fibres and their health benefits.

Table 2 : Analysis Results for Almond Shell Powder

Analysis	Almond Shell Powder
Moisture Content%	6.50± 2.73
Ash %	1.32± 0.024
Protein %	5.02± 0.091
Carbohydrate%	41.60± 5.06
Reducing Sugar %	1.29± 0.11
Non-reducing sugar%	4.90 ±0.21
Total Sugar%	6.19±0.019
Crude Fibre%	45.20±0.03
Cellulose %	28.22± 3.67
Hemicellulose %	32.44± 2.97
Lignin %	14.24± 0.06
Pectin %	0.55± 0.08

All values are means of three determination± standard deviation (±SD)

Table 3 is showing the impact on the physical aspect of control biscuits at various degrees of almond shell powder incorporation. Following addition of almond shell powder to the control biscuits, it was found that the diameter, thickness, volume and weight of all the almond shell powder incorporated biscuits were greater than the control biscuits. It was further observed that the diameter and weight of almond shell biscuits was increasing with increasing level of almond shell incorporation, whereas the volume was decreasing with increasing level of almond shell incorporation. The thickness was high with low level and less with high level of incorporation of almond shell powder in the formulation of control biscuits. Biscuits' spread ratio and spread factor were increases. The spread ratio, spread factor and density of all the almond shell incorporated biscuits were found to be less than the control biscuits. The similar results were observed by Huma Parvin, et al, 2017. After development of fibre rich biscuits by incorporating carrot and beetroot pomace powder. However the lowest spread ratio, spread factor and density were observed with low incorporation level (5 %) and highest spread ratio, spread factor and density was observed with high incorporation level (30 %). The physical results thus concluded that almond shell incorporated biscuits had greater diameter, thickness, volume and weight than control biscuits and less spread ratio, spread factor and density than control biscuits. However magnitude of increase and decrease in these physical parameters were the function of level of incorporation of almond shell in the formulation of control biscuits.

Table 3 : Effect of Different Levels of Almond Shell Powder Incorporation on the Physical Analysis of Control Biscuits

Parameters	Level of Almond Shell Fortification						
	0%	5%	10%	15%	20%	25%	30%
Diameter (mm)	55.23 ± 0.23 ^a	55.51 ± 0.20 ^a	55.54 ± 0.13 ^a	55.62 ± 0.22 ^b	55.65 ± 0.21 ^b	55.91 ± 0.21 ^c	55.96 ± 0.20 ^c
Thickness (mm)	5.20 ± 0.24 ^a	5.94 ± 0.2 ^b	5.89 ± 0.15 ^b	5.78 ± 0.22 ^c	5.56 ± 0.16 ^d	5.53 ± 0.12 ^d	5.51 ± 0.28 ^d
Spread Ratio (%)	10.62 ± 0.12 ^a	9.34 ± 0.03 ^b	9.42 ± 0.21 ^b	9.62 ± 0.33 ^c	10.00 ± 0.81 ^d	10.11 ± 0.74 ^d	10.15 ± 0.93 ^d
Spread factor (%)	100 ± 0.02 ^a	87.94 ± 0.04 ^b	88.70 ± 0.08 ^c	90.58 ± 1.2 ^d	94.16 ± 0.45 ^e	95.19 ± 0.33 ^f	95.57 ± 1.02 ^f
Volume (cm ³)	4.50 ± 0.13 ^a	5.14 ± 0.38 ^b	5.05 ± 1.20 ^{b,c}	4.97 ± 0.38 ^c	4.80 ± 1.84 ^d	4.82 ± 1.28 ^d	4.82 ± 0.43 ^d
Density (g/cm ³)	1.85 ± 0.10 ^a	1.63 ± 0.2 ^{a,b}	1.68 ± 0.11 ^{b,c}	1.72 ± 0.15 ^{c,d}	1.79 ± 0.11 ^d	1.80 ± 0.24 ^{d,e}	1.82 ± 0.17 ^e
Weight (g)	8.34 ± 0.06 ^a	8.41 ± 0.13 ^{a,b}	8.49 ± 0.15 ^{b,c}	8.57 ± 0.02 ^{c,d}	8.62 ± 0.15 ^{d,e}	8.71 ± 0.41 ^e	8.80 ± 0.22 ^g

All values are the means of ten biscuits determination ±standard deviation (SD) Means not sharing a common superscript letter in a row are significantly different at p<0.05 as assessed by t-Test.

Table 4 shows the effect of different levels of almond shell powder incorporation on the chemical parameters of control biscuits. The moisture content of all almond shell incorporated biscuits was slightly greater than control biscuits but as the level of incorporation of almond shell powder increased the moisture content of biscuits was decreasing. The level of fat content, protein content, carbohydrate and Energy of almond shell incorporated biscuits were slightly decreasing as compared to control

biscuits due to increased in the level of almond shell incorporation. The level of fibre content and ash content was increasing in almond shell incorporated biscuits as compared to the control biscuits because the almond shell contained a high level of fibre. While no significant changes were observed in acid insoluble ash or acidity of extracted fat. Similar result was also observed in Study of Whey Protein Concentrate Fortification in Cookies Variety Biscuits by Parate et al, 2011.

Table 4: Effect of Different Levels of Almond Shell Powder Incorporation on the Chemical Analysis of Control Biscuits

Parameters	Level of Almond Shell Fortification						
	0%	5%	10%	15%	20%	25%	30%
Moisture Content (%)	3.2 ± 2.12 ^a	3.62 ± 1.21 ^b	3.59 ± 1.38 ^b	3.44 ± 2.35 ^b	3.3 ± 0.7 ^{a,b}	2.97 ± 0.56 ^c	2.56 ± 3.47 ^d
Ash (%)	0.36 ± 0.01 ^a	0.38 ± 0.02 ^a	0.38 ± 0.02 ^a	0.39 ± 0.01 ^{a,b}	0.44 ± 0.02 ^b	0.52 ± 0.0 ^b	0.61 ± 0.01 ^c
Fat (%)	21.41 ± 0.72 ^a	19.9 ± 0.27 ^a	19.85 ± 0.70 ^a	19.78 ± 0.05 ^b	19.65 ± 0.01 ^b	19.56 ± 0.01 ^b	19.47 ± 0.06 ^b

Parameters	Level of Almond Shell Fortification						
	0%	5%	10%	15%	20%	25%	30%
Acidity of	0.27 ±	0.29 ±	0.30 ±	0.28 ±	0.32 ±	0.30 ±	0.28 ±
Extracted Fat (%)	0.5 ^a	0.04 ^a	0.04 ^a	0.08 ^a	0.04 ^a	0.06 ^a	0.03 ^a
Crude Fibre (%)	1.28 ±	4.56 ±	7.89 ±	11.23 ±	14.51 ±	17.60 ±	20.87 ±
	0.02 ^a	0.2 ^b	0.15 ^c	0.004 ^d	0.04 ^e	0.17 ^f	0.25 ^g
Protein (%)	8 ±	7.88 ±	7.62 ±	7.44 ±	7.06 ±	6.88 ±	6.72 ±
	0.25 ^a	0.01 ^a	0.05 ^{a,b}	0.21 ^b	0.08 ^{b,c}	0.06 ^c	0.11 ^c
Carbohydrates	65.67 ±	63.66 ±	60.67 ±	57.72 ±	55.04 ±	52.47 ±	50.22 ±
(By differ.) (%)	5.02 ^a	5.00 ^a	4.87 ^b	2.23 ^c	0.11 ^d	4.32 ^e	1.22 ^f
Acid Insoluble	0.031 ±	0.023 ±	0.026 ±	0.029 ±	0.024 ±	0.030 ±	0.026
ash (%)	0.21 ^a	0.01 ^a	0.24 ^a	0.31 ^a	0.12 ^a	0.12 ^a	± 0.10 ^a
Energy Kcal/ 100 gm	477.62 ^a	468.74 ^b	459.73 ^c	450.90 ^d	443.29 ^d	433.20 ^e	417.15 ^e

All values are the means of ten biscuits determination ± standard deviation (SD) Means not sharing a common superscript letter in a row are significantly different at $p < 0.05$ as assessed by t-Test.

The sensory analysis, of almond shell incorporated biscuits is shown in Table 5. The highest overall acceptability score was received by the biscuits incorporated with 20% almond shell- next to control biscuits. Afterward, the sensory score declined up to the 30% almond shell incorporated biscuit. It was observed that as the level of incorporation of almond shell powder increased, it lead to the formation of roughage on

the surface of the biscuit due high amount of fibres. Also there developed slight inferior taste and darkening of colour biscuits with increasing level of almond shell incorporation. This roughness of surface, inferior taste and darkening in colour was the cause for less sensory score received by biscuits incorporated with high level of almond shell Lebesi, D.M. and Tzia, C. 2011

Table 5: Effect of Different Levels of Almond Shell Powder Incorporation on the Sensory Analysis of Control Biscuits

Parameters	Control	5%	10%	15%	20%	25%	30%
Aroma	8.5±0.20	8.5±0.02	8.3±0.10	8.2±0.07	8.4±0.05	7.6±0.91	7.4±0.44
Colour	8.9±0.41	8.4±0.21	8.3±0.32	8.4±0.40	8.4±0.11	8.2±0.25	7.9±0.04
Texture	8.6±0.5	8.8±0.45	8.7±0.41	8.6±0.53	8.6±0.22	8.3±0.11	8.1±0.17
Taste	8.7±0.23	8.2±0.61	8.2±0.13	7.8±0.55	8.3±0.8	7.2±0.12	7±0.03
Appearance	8.8±0.06	8.5±0.30	8.2±0.24	7.7±0.20	8.4±0.12	7.7±0.21	7.4±0.04
Overall	8.9±0.5	8.2±0.22	8±0.0	8.1±0.00	8.4±0.17	7.2±0.50	7.1±0.2
Acceptability							

All values are means of ten determination ± standard deviation (SD)

CONCLUSION

Followings are the conclusions drawn from the said study:

1. The powder made from defatted almond shells was a rich source of fibre and it is

2. Incorporation of almond shell powder however brings changes in the various possible to prepare acceptable quality fibre rich biscuits by its incorporation in the formulation of control biscuits.

parameters (physical, chemical and sensory) of control biscuits depending on the level of incorporation.

3. The incorporation of almond shell powder from 5% to 30% level in control biscuits brings an increase in diameter, thickness, volume and weight and decrease in spread ratio, spread factor and density of the control biscuits from 30% to 5% level.
4. Almond shell incorporation however doesn't bring much deviation in chemical parameters except increase in fibre content from 1.28 to 20.87% from in control biscuits.
5. When incorporated at high level that is more than 25% addition of almond shell powder brings unacceptable impact on sensory measures such as hardness, colour darkening and inferior taste.
6. The maximum level of almond shell powder that can be incorporated in the given formulation of control biscuits is 20%.

The further study on Almond Shells should be done to evaluate the presence of vitamins and minerals content and to develop various bakery products, snacks and fermented products and beverages, etc. The potential application towards the utilization of Almond shells can be helpful for almond industries to build up the successful economy by re-utilizing almond shell as a by-products for the production system.

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Preliminary in-vitro acaricidal screening of selected Indian medicinal plants against *Rhipicephalus microplus*

Dharmik A. Shah, Prachi K. Nariyani, Punit R. Bhatt*, Kishorkumar R. Sorathia
Bhanubhai N. Suhagia

Faculty of Pharmacy, Dharmsinh Desai University, Nadiad

*Email: puns003@gmail.com

ABSTRACT

Rhipicephalus microplus is also known as Asian blue tick or cattle tick. This tick is prominent in all parts of India including Gujarat. In this study, in-vitro acaricidal activity was evaluated by the Adult Immersion Test against *Rhipicephalus (Boophilus) Microplus* also known as cattle ticks. Aqueous extracts of various medicinal plants were evaluated for their acaricidal activity. In the assay, test solutions were prepared to consist of 100, 500 and 1000 µg/ml of extracts and 10 to 50% v/v solution of oils in 50% v/v ethanol. Ticks were immersed in the test solutions for 2 minutes and mortality of the ticks was recorded after 24 hours. Except for the test solution of aqueous extract of *A. marmelos* leaves (100 µg/ml), ticks died (100% mortality) in all the test solutions containing extracts and oils. All the tested plants could be used against *R. microplus* as a potential alternative to chemical-based drugs.

Keywords : Acaricidal, Tick, Herbal, Medicinal plants extract, *Rhipicephalus (Boophilus) microplus*

INTRODUCTION

Ticks are harmful hematophagous arthropods that parasitize domestic and wild animals and result in significant financial damages, thereby contributing to food scarcity with an approximate global expense of prevention and efficiency losses of 7 billion USD annually. Their impacts are varied, such as diminished growth and lactation, paresis/poisoning, and dissemination of tick-borne diseases (TBDs) that impair production or induce fatality (Nchu *et al.*, 2012).

Globally, tick control relies primarily on the recurrent application of acaricides, which have caused issues related to environmental degradation, milk and meat adulteration, and the emergence of resistance leading to increased cost of control. In India, for the last several years, ticks are chiefly controlled by using various synthetic acaricides. Nevertheless, ticks have acquired resistance

against commercial acaricides in India with the extensive, under- or over-diluted, and regular use of these substances (Obaid *et al.*, 2022). Therefore, there is a need for new tick control methods to overcome the disadvantage associated with the use of synthetic chemicals. One alternative control method could be phytotherapy, a vital component of ethnoveterinary medicine (Madzimore *et al.*, 2011).

The use of natural products, predominantly acaricides from the plant origin used for the management of ticks, has been the centre of research in many countries, mainly to counteract the evident increasing prevalence of acaricide-resistant tick populations (Dzemo *et al.*, 2022). The application of botanicals for the management of ticks is an indigenous practice in India, where most low-income farmers use plant substances to treat ectoparasites and endoparasites of livestock (Wanzala, 2017). Acaricidal activity of crude extracts from various medicinal plants

against ticks has been well documented. The phytoextracts exhibit acaricidal properties through different mechanisms: eliminating adult ticks, diminishing tick feeding, and impeding egg hatching, moulting, fertility, and viability of eggs, etc. (Kemal *et al.*, 2020).

Thus, it is quite obvious that acaricidal effectiveness of natural remedies can considerably contribute to manage tick infestation in a more economical and sustainable manner (Rajput *et al.*, 2006). Furthermore, there is a possibility to develop sources of acaricides from the existing medicinal plants which can be easily produced by livestock producers themselves or processed by small-scale industries and used as inexpensive and effective natural acaricide for tick management. Implementing a successful tick management strategy appropriate to a specific livestock production system is a dual benefit, managing ticks and also the TBDs (Quadros *et al.*, 2020). Therefore, it is essential to conduct an acaricidal effectiveness evaluation of botanicals which can be used in-future for the development of effective acaricidal herbal

formulations. In the present work, attempts have been made to evaluate an acaricidal activity of locally available medicinal plants at various concentrations or percentage.

MATERIALS AND METHODS

Collection, identification and processing of plant materials

The plants were collected from the local surrounding areas of Nadiad and Anand (22°40'27.6"N 72°53'02.6"E). Some plants like *Cassia absus*, *Enicostema littorale*, etc., were bought directly from the market as their powder form. Whereas some plants like *Datura stramonium*, *Datura metel*, etc. were collected from the local areas like the Faculty of Pharmacy, Dharmsinh Desai University campus garden (Table 1). The plants were identified by one of the authors (PRB) and voucher specimens were submitted to the department for future reference. All the collected plant materials were dried in shed at room temperature for up to 10 days. After drying, powder was made by mixer grinder and stored in an air-tight plastic container for further use.

Table 1 : List of medicinal plant used for in-vitro acaricidal activity

Sr. No.	Botanical Name	Family	Vernacular name	Part used
1.	<i>Aegle marmelos</i>	Rutaceae	Billi	Leaves
2.	<i>Annona squamosa</i>	Annonaceae	Sitaphal	Seed oil
3.	<i>Azadirachta indica</i>	Meliaceae	Limdo	Fruit oil
4.	<i>Calotropis procera</i>	Apocynaceae	Ankado	Flowers
5.	<i>Cassia absus</i>	Fabaceae	Chimed	Seed
6.	<i>Centratherum anthelminticum</i>	Asteraceae	Kalijiri	Seed
7.	<i>Datura metel</i>	Solanaceae	Dhaturo	Leaves
8.	<i>Datura stramonium</i>	Solanaceae	Dhaturo	Leaves
9.	<i>Embelia ribes</i>	Primulaceae	Vaavading	Seed
10.	<i>Enicostema littorale</i>	Gentianaceae	Mamejavo	Leaves
11.	<i>Justicia adhatoda</i>	Acanthaceae	Ardusi	Leaves
12.	<i>Lantana camara</i>	Verbenaceae	Gandhari	Leaves & Flower
13.	<i>Millettia pinnata</i>	Fabaceae	Karanj	Leaves
14.	<i>Moringa oleifera</i>	Moringaceae	Saragavo	Leaves
15.	<i>Tagetes erecta</i>	Asteraceae	Galgota	Flower
16.	<i>Trigonellia foenum graceus</i>	Fabaceae	Methi	Seed
17.	<i>Vitex negundo</i>	Verbenaceae	Nagod	Leaves

Preparation of extracts

Except oils, the extracts were prepared by soaking the powder in the suitable solvent in the ratio of 1:10 (for each 1 g powder 10 ml extracting solvent was added) in a conical

flask for at least 5 to 7 days. Then, the content was filtered; filtrate was collected, dried below 40°C in petri dish. The dried extracts were scraped and stored in an air-tight plastic container (Table 2).

Table 2 : List of medicinal plant, its part and type of extract used

Sr. No.	Vernacular Name of plant	Part of plant	Extract used
1.	Aakdo	flower	water extract
2.	Billi	leaves	water extract
3.	Chimed	seed	water extract
4.	Chimed	seed	methanol extract
5.	Black datura	leaves	methanol extract
6.	White datura	leaves	methanol extract
7.	Galgota	flower	water extract
8.	Gandhari	flower	water extract
9.	Gandhari	leaves	water extract
10.	Kalijiri	seed	water extract
11.	Karanj	leaves	water extract
12.	Mamejavo	leaves	water extract
13.	Mamejvo	leaves	methanol extract
14.	Methi	seed	methanol extract
15.	Methi	seed	water extract
16.	Nagod	leaves	water extract
17.	Nagod	leaves	methanol extract
18.	Sitaphal	seed	water extract
19.	Vasaka	leaves	water extract
20.	Vasaka	leaves	methanol extract
21.	Vavding	seed	water extract

Collection of ticks for in-vitro testing

The ticks were collected from various livestock owners of Nadiad and surrounding regions. The ticks were collected mainly from the ground surface near the cattle and cow feeding regions or their staying places. The ticks were then brought to the lab by keeping them in containers that allowed some oxygen and air to pass. Once brought into the labs, the ticks were then cleaned from the dirt and the foreign matter present in them and then stored in the container until the in-vitro test was to be performed (Figure 1).

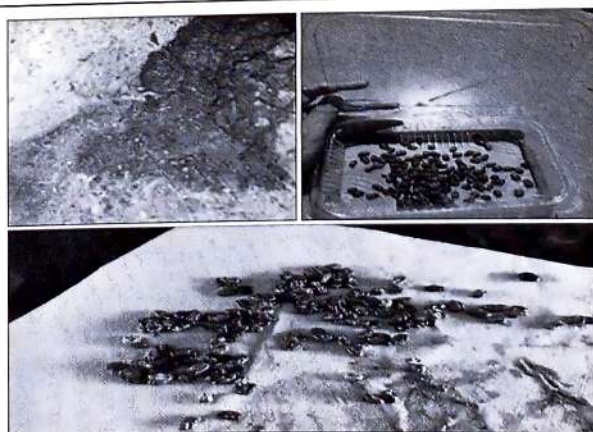


Figure 1 : Collection of ticks

Preparation of different concentrations of the test samples

Preparation of stock solution (1000 microgram per ml) - 0.1 g of the prepared extract was taken and then it was diluted with 10 ml of water. The stock solution was then diluted to 100 micrograms per ml and 500 micrograms per ml. All 3 concentrations of the extracts were then labelled and kept for testing the acaricidal activity. All the oils were separately mixed with a sufficient volume of 50% v/v ethanol in water to get the desired concentrations. All these concentrations were then labelled and tested for their acaricidal activity.

In-vitro testing of the acaricidal activity

The prepared solutions of different concentrations were tested for their acaricidal activity with ticks by performing Adult Immersion Test. The solutions of test extract or oils were taken in a suitable apparatus. Ticks were dipped in the solution of extract/oil for 2 min. After two minutes, ticks were put in a petri dish containing moistened filter paper. Petri dishes were put in an incubator for 24 hours. The ticks were then observed in the daylight after 24 hours if they were alive or dead. If the ticks were found alive, they were then kept for observation for their egg-laying capacity.

RESULTS AND DISCUSSION

All the plant materials were subjected to cold extraction i.e. maceration process (Figure 2). The per cent for each selected extracts were calculated as % w/w per 100 g dry plant material (Table 3).

Water extract of *chimed seed*, *galgota* flower, *mamejava* leaves, *methi* seed, *sitaphal* seed, *gandhari* flower, *gandhari* leaves, *kalijiri* seed and *vavding* seed showed 100% mortality. Methanol extract of *methi* seed, *nagod* leaves also showed 100% mortality of ticks in

all the concentrations. However, methanol extract of *chimed* seed and white *datura* leaves and *karanj* leaves water extract did not show any mortality. In this assay, 100% water and methanol were used as control as all the extracts were prepared either in water or methanol. Control did not show any mortality (Table 4). In case of neem seed and *karanj* seed oil which were prepared in ethanol, 100% mortality was observed from 10 to 50% oil. Control sample (50% ethanol) showed no mortality (Table 5). All the samples were assayed at constant incubation temperature.



A. Preparation of Extract



B. Drying in a hot air oven

Figure 2 : Extraction and drying of the plant extract.

Table 3 : Per cent yield of different extracts of various medicinal plants

Name of extract	Percentage yield (%w/w)	Name of extract	Percentage yield (%w/w)
<i>Aakdo</i> flowers water extract	8.3	<i>Karanj</i> leaves water extract	9.8
<i>Billi</i> leaves water extract	10.3	<i>Mamejavo</i> leaves water extract	9.9
<i>Chimed</i> seed methanol extract	13.0	<i>Mamejvo</i> methanol extract	11.1
<i>Chimed</i> seed water extract	10.3	<i>Methi</i> seed methanol extract	19.9
<i>Black datura</i> methanol extract	6.3	<i>Methi</i> seed Water extract	21.4
<i>White datura</i> methanol extract	9.7	<i>Nagod</i> leaves methanol extract	9.8
<i>Galgota</i> flower water extract	2.8	<i>Nagod</i> leaves water extract	9.1
<i>Gandhari</i> flower water extract	6.5	<i>Sitaphal</i> seed water extract	16.8
<i>Gandhari</i> leaves water extract	3.4	<i>Vasaka</i> leaves methanol extract	10.7
<i>Kalijiri</i> seed water extract	6.8	<i>Vasaka</i> leaves water extract	7.9
		<i>Vavding</i> seed water extract	1.5

Table 4 : Acaricidal activity of extracts

Name of the medicinal plant extract	No. of ticks included in assay	Total No. of dead ticks/percentage mortality		
		The concentration of the extract ($\mu\text{g/ml}$)		
		100	500	1000
Control (Distilled water)		0 (n=5)		
<i>Aakdo</i> flowers water extract	9	1 (n=3), 33%	1 (n=3), 33%	2 (n=3), 66%
<i>Billi</i> leaves water extract	15	0 (n=5), 0%	5 (n=5), 100%	5 (n=5), 100%
<i>Chimed</i> seed methanol extract	9	0 (n=3), 0%	0 (n=3), 0%	0 (n=3), 0%
<i>Chimed</i> seed water extract	15	5 (n=5), 100%	5 (n=5), 100%	5 (n=5), 100%
<i>Black datura</i> methanol extract	9	2 (n=3), 67%	1 (n=3), 33%	1 (n=3), 33%
<i>White datura</i> methanol extract	9	0 (n=3), 0%	0 (n=3), 0%	0 (n=3), 0%
<i>Galgota</i> flower water extract	6	2 (n=2), 100%	2 (n=2), 100%	2 (n=2), 100%
<i>Gandhari</i> flower water extract	6	2 (n=2), 100%	2 (n=2), 100%	2 (n=2), 100%

Name of the medicinal plant extract	No. of ticks included in assay	Total No. of dead ticks/percentage mortality		
		The concentration of the extract ($\mu\text{g/ml}$)		
		100	500	1000
<i>Gandhari</i> leaves water extract	6	2 (n=2), 100%	2 (n=2), 100%	2 (n=2), 100%
<i>Kalijiri</i> seed water extract	9	3 (n=3), 100%	3 (n=3), 100%	3 (n=3), 100%
<i>Karanj</i> leaves water extract	9	0 (n=3), 0%	0 (n=3), 0%	0 (n=3), 0%
<i>Mamejavo</i> leaves water extract	9	3 (n=3), 100%	3 (n=3), 100%	3 (n=3), 100%
<i>Mamejvo</i> methanol extract	9	1 (n=3), 33%	0 (n=3), 0%	0 (n=3), 0%
<i>Methi</i> seed methanol extract	9	3 (n=3), 100%	3 (n=3), 100%	3 (n=3), 100%
<i>Methi</i> seed Water extract	9	3 (n=3), 100%	3 (n=3), 100%	3 (n=3), 100%
<i>Nagod</i> leaves methanol extract	9	3 (n=3), 100%	3 (n=3), 100%	3 (n=3), 100%
<i>Nagod</i> leaves water extract	9	0 (n=3), 0%	0 (n=3), 0%	3 (n=3), 100%
<i>Sitaphal</i> seed water extract	6	2 (n=2), 100%	2 (n=2), 100%	2 (n=2), 100%
<i>Vasaka</i> leaves methanol extract	9	2 (n=3), 67%	1 (n=3), 33%	2 (n=3), 67%
<i>Vasaka</i> leaves water extract	9	2 (n=3), 67%	1 (n=3), 33%	3 (n=3), 67%
<i>Vavding</i> seed water extract	6	2 (n=2), 100%	2 (n=2), 100%	2 (n=2), 100%
Control (methanol/ water)	3		0 (n=3)	

"n" here shows the total number of ticks taken for the assay and the number outside the bracket shows a total number of ticks died. The number of ticks may vary due to their availability or the number of ticks collected.

Table 5 : Acaricidal activity of various oils with different concentrations

Concentration of oil	Number of ticks evaluated	Number of ticks dead	% mortality
Neem oil			
10 %	4	4	100
20 %	4	4	100
30 %	4	4	100
40 %	4	4	100
50 %	4	4	100
Control	4	0	0
Karanj oil			
10 %	4	4	100
20 %	4	4	100
30 %	4	4	100
40 %	4	4	100
50 %	4	4	100
Control	4	0	0

Nyahangare *et al.* (2019) reported that *C. absus* seed possesses acaricidal action. The activity might be due to the quaternary alkaloids like chaksine and isochaksine present in the seed. These alkaloids are also reported for its antibacterial and antifungal action (Ahmad *et al.*, 1935). Ghotge and Ramdas (2020) cited *Enicostemma littorale* as deworming plant as per the field trials carried out on animals as a part of ethnoveterinary practices. Swertiamarin is a glycoside compound present in *E. littorale* which might be responsible for the action. Worku (2018) reported the use of *Embelia ribes* for its anti-parasitic and anti-nematode activity. The plant have been widely used in India and Africa under the ethnoveterinary practices. Elango and Rahuman (2011) studied and reported acaricidal activity of *Aegle marmelos* against *Boophilus microplus* and other species of the ticks. Presence of various phytochemicals like aegelin, marmenol, marmin, marmelin, marmelosin, marmelide, psoralen, limonene,

anhydromarmelin, betulinic acid, α -phellandrene, etc. Oliveira De Sousa *et al.* (2020) showed the acaricidal activity of *Lantana camara* essential oil. GC/MS analysis showed the presence of various molecules like Bicyclogermacrene, isocaryophyllene, valencene and germacrene-D. Results showed that leaves are also possessing acaricidal action. Adenubi *et al.* (2016) reviewed various plant extract for tick management and ethnoveterinary use. *Tagete erecta* exhibited its action due to the presence of phytochemicals like Thiophenes, flavonoids, carotenoids, triterpenoids. Elkertati *et al.* (2013) studied the acaricidal activity of *Trigonella foenum graecum*. The results showed that *T. foenum graecum* extract exhibited strong acaricidal action against *Tetranychus urticae*. In the present results, 100% mortality was observed in case of *methi* seed extract. Garg *et al.* (2019) reported an ethnoveterinary practices in Rajasthan. It has been observed that most

farmers use *C. anthelminticum* with other plants for tick infestation. In the present research, *kalijiri* showed very good acaricidal action against *B. microplus* tick. Jadhav *et al.* (2021) reported the acaricidal activity of chloroform extract of *A. vasica* against *R. microplus* ticks. The acaricidal action of *A. vasica* might be due to alkaloid present in the leaves like vasicine and vasicinone, are the two major alkaloids. Sharma *et al.* (2022) developed the phytoformulation contains *Annona squamosa* for the management of tick infestation. The formulation showed more than 70% of efficacy in the field trial. In our research, seeds of *A. squamosa* showed good action against tick. Denardi *et al.* (2011) reported the vitallogenesis action of neem leaves against *Rhipicephalus sanguineus*. In the present research, neem oil showed very good action against *R. microplus* ticks. It may be concluded that azadirachtin present in the plant might be responsible for the acaricidal action. Raghav *et al.* (2019) reviewed the use of *P. pinnata* seed oil for its various applications like pesticidal, insecticidal and acaricidal activities. Karanjin from seed oil is an active constituent of the oil which might be responsible for the acaricidal activity in the present research.

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PERIOD OF EXPERIMENT

The total duration of experiment was 6 months.

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Effect of nutrition training on adolescent girls understanding of balanced diet

Mrs. Manju¹, Kavita Kachhawa², Simple Jain³, Ankur M Kumar⁴ and Manju Gupta⁵

^{1,2}Department of Home Science, University of Rajasthan, Jaipur

³College of Community and Applied Science, SDAU, Dantiwada, Gujarat

⁴Department of Chemistry, University of Rajasthan, Jaipur

⁵College of Community and Applied Sciences, M.P.U.A.T., Udaipur

email: manjuch059@gmail.com

ABSTRACT

With rising concerns about malnutrition and diet-related health issues among adolescent girls, there is a pressing need to enhance nutritional knowledge and promote healthy dietary habits. Therefore, a study was conducted to assess the effectiveness of nutrition training on understanding of balanced diet among rural adolescent girls aged between 15-18 years. Locale of the study was Dhodh panchayat Samiti of Rajasthan. A total of randomly selected 100 rural adolescent girls were the sample of the study. Data were collected using a questionnaire and analysed by using frequency, mean percentage and paired t-test. Findings revealed significant ($p \leq 0.05, 0.01$) improvement of knowledge of adolescent girls regarding balanced diet. This was because the training was participatory in nature and effective use of training methods and audio-visual aids.

Keywords : Adolescent girls, Nutrition empowerment, Balanced diet, Knowledge

INTRODUCTION

Adolescence marks a period of rapid physical growth and cognitive development. It is also a critical stage for socio-emotional changes. Within this demographic, adolescent girls represent a particularly vulnerable group, often facing unique challenges related to societal norms, body image perceptions, and nutritional needs. Nutritional requirements of adolescence are heightened to support overall health and well-being. However, this developmental stage is also characterized by increased autonomy and exposure to various environmental influences, including dietary choices tempted by peers, media, and cultural factors. Consequently, adolescents may adopt dietary patterns that deviate from recommended nutritional guidelines, predisposing them to nutritional deficiencies and associated health risks.

Training programmes tailored to the specific needs of adolescent girls have the power to ignite profound change, empowering them with knowledge, skills, and confidence to navigate the challenges they face. They have a transformative impact on adolescent girls making them realize their full potential, lead fulfilling lives, and contribute meaningfully to the world around them. By investing in their education, health, and empowerment, a ripple effect of positive change is created that benefits individuals, families, and societies as a whole.

Training adolescent girls on different aspects of nutrition is essential for promoting their health, empowering decision-making, preventing malnutrition and eating disorders, fostering positive body image, addressing gender-specific nutritional needs, promoting lifelong healthy habits, and empowering communities to create a culture of health and well-being. Therefore, a study was

conducted on effectiveness of nutrition training on adolescent girls understanding of balanced diet.

percentage, mean percentage and paired t-test.

METHODOLOGY

The study was conducted in the Dhod Panchayat Samiti of Sikar district, Rajasthan. Three government schools—Government Senior Secondary School Churoli-Khakoli, Sihot Chhoti, and Phagalawa—were selected randomly from a list provided by the District Education Officer. A total of 100 rural adolescent girls, aged 15-18, were selected randomly from these schools. Three days participatory training regarding balanced diet was organised. Each training consisted of 25 participants and total four trainings were conducted for the sample of 100 rural adolescent girls. This age group was chosen due to its significance as the typical age for marriage in rural areas and empowering girls in this demographic to make informed decisions for themselves and their families' well-being is crucial for community health and development. Data collection was done using a questionnaire. The knowledge test developed by Gupta (2006) was slightly modified and used. The questionnaire schedule consisted of multiple-choice questions and scoring was done on a 2 point-continuum i.e. correct and incorrect. Each correct response was assigned score one, while the incorrect response was assigned zero. Data were analysed using frequency,

RESULTS AND DISCUSSION

Knowledge about balanced diet is essential for adolescent girls as it empowers them to make informed choices about their nutrition, supports physical and mental well-being, and lays the foundation for a lifetime of good health. Results of knowledge test conducted before and after exposure to the training are presented in this section.

Overall knowledge of respondents about balanced diet

Table 1 indicates that before exposure to the training programme, almost half of the respondents (43% and 46%) possessed low and medium knowledge regarding balanced diet, while only 11 per cent respondents consisted high knowledge. Table further reveals that after exposure to training, most of the respondents (96%) shifted to high knowledge category, while only 4 per cent respondents had medium knowledge regarding balanced diet. Notably, after exposure to the training programme, none of the respondents possessed low knowledge about balanced diet. The MPS of gain in knowledge of respondents was 43 reflecting higher effect of training on the knowledge of respondents.

Further, paired t-test was performed and t-value of the test reveal that it was highly significant both at .05 and .01 per cent level of significance.

Table 1: Overall knowledge of respondents regarding balanced diet

Levels of knowledge	Knowledge			t-value
	Before exposure (%)	After exposure (%)	Gain (MPS)	
Low	43	0		
Medium	46	4		
High	11	96	43	23.812**
MPS	40.7	83.7		

** Significant at .05 and .01 percent

Results of the study are in conformity with who assessed the effect of school menstrual education programme and observed significant improvement in the knowledge, beliefs and practices of menstrual hygiene among adolescent girls. Component wise knowledge of respondents regarding balanced diet

The whole idea of balanced diet was divided into four components i.e. significance of food and concept of balanced diet, different food groups and their functions, portion size and amount of food stuffs to be included in daily diet and deficiency diseases caused due to absence of nutrients in the diet. Component wise assessment of knowledge of respondents was done before and after exposure to the training programme.

i. **Significance of food and concept of balanced diet**

As presented in Table 2, before exposure to the training programme 70 per cent respondents were aware that food provides energy, while 62 per cent also knew that food is needed for proper growth and development, while half of the respondents (50%) were able to relate food with prevention from diseases. However, only 27 per cent of the respondents could explain the concept of balance diet before they were exposed to the training programme. Notably, after exposure to the training programme, most of the respondents (81-96 %) possessed knowledge about different functions of food and were able to explain the concept of balance diet.

Table 2 : Distribution of respondents by their knowledge about functions of food and concept of balanced diet

		n=100	
S. No.	Items	Knowledge	
		Before exposure f / (%)	After exposure f / (%)
1.	Significance of food		
	a. Provide energy	70	92
	b. Proper growth and development	62	93
	c. Prevention from disease	50	96
2.	Concept of balanced diet		
	Diet that provides all nutrients in required amounts and proper proportions.	27	81

Fariba *et.al* (2021) reported the similar results that significant improvement in the mean percent score of knowledge, attitude and practices as a result of intervention of blended educational programme on iron deficiency anaemia among adolescent girls.

ii. **Different food groups and their functions**

Data presented in Table 3 reveal that before exposure to the training programme, more than half of the

respondents (50-62%) had knowledge about functions of cereals, millets and pulses. Similarly, before getting exposed to the training programme, 40 per cent respondents confirmed that fruits and vegetables help in blood formation, 49 per cent respondents knew that milk and animal products are important for proper growth and development and 53 per cent respondents also possessed the knowledge that oils, fats and nuts are

necessary for healthy skin and tissues. However, it can be inferred from the table that only less than 40 per cent respondents had knowledge about rest of the functions of milk and animal foods, fruits and vegetables, and oils, fats and nuts. Further, it can be observed from the

table that after exposure to the training, there was drastic gain in knowledge of the respondents regarding all aspects of food groups and their functions. Table 3 also asserts that more than 80 per cent of the respondents had knowledge regarding different food groups and their functions.

Table 3 : Distribution of respondents by their knowledge about different food groups and their functions

S. No.	Items	Knowledge	
		Before exposure	After exposure
		f / (%)	f / (%)
1.	Cereals, Millets and Pulses		
	a. Provide energy / Strength	62	96
	b. Rich source of dietary fibre	50	100
2.	Milk and Animal Foods		
	a. Proper growth and development	49	88
	b. Repair and maintenance of body tissues	21	79
	c. Strong bones and teeth	36	89
3.	Fruits and Vegetables		
	a. Help in blood formation	40	92
	b. Protect the body from diseases	30	89
	c. Prevent constipation	29	86
4.	Oils, Fats and Nuts		
	a. Provide energy	21	83
	b. Help fight diseases	25	80
	c. Healthy skin and tissues	53	84

iii. Portion size and amount of food stuffs to be included in daily diet

Knowledge of the respondents was assessed regarding portion size and amount of food stuffs to be included in daily diet and found that prior to exposure to the training, almost 40

percent of the respondents possessed knowledge regarding amount of food stuff to be consumed in daily diet. The table further confirms that after being exposed to the training, over 80 per cent of the respondents were found to have gained knowledge about amount of food stuffs to be consumed in daily diet.

Table 4 : Distribution of respondents by their knowledge about portion size and amount of food stuffs to be included in daily diet

		n=100	
S. No.	Items	Knowledge	
		Before exposure f / (%)	After exposure f / (%)
1.	Cereals, millets and pulses	36	87
2.	Milk and animal foods	39	91
3.	Fruits and vegetables	43	82
4.	Oils, fats and nuts	41	86

iv. Deficiency diseases caused due to absence of nutrients in the diet

Insufficient intake of essential nutrients can lead to various deficiency diseases such as Vitamin A deficiency, anaemia, and Protein Energy Malnutrition (PEM). According to Table 4, before receiving the training, only 46 percent of the

respondents had knowledge about anaemia, while 39 percent knew about Vitamin A deficiency, and merely 21 percent had awareness regarding PEM. However, after the training session, an overwhelming percentage of the respondents (more than 86%) gained knowledge about these deficiency diseases.

Table 5 : Distribution of respondents by their knowledge about deficiency diseases caused due to absence of nutrients in the diet

		n=100	
S. No.	Items	Knowledge	
		f / (%)	f / (%)
	Deficiency diseases		
1.	Protein-Energy Malnutrition	23	86
2.	Anaemia	46	89
3.	Vitamin A deficiency	39	87

Results of the study are supported by Rana and Kaur (2019) who also concluded positive impact of nutrition education on knowledge scores of adolescent girls regarding different aspects of nutrition during lifecycle.

Conclusion

The results of the study conclude that the training was effective in educating the respondents about the importance of a healthy balanced diet and the types of food that can contribute to good health. The

participatory nature of the training program and the use of appropriate training were very effective for success of training program. The training program actively engaged the participants in the learning process, which enabled them to better understand the information being presented. The use of effective training methods such as interactive sessions and audio-visual aids made the training program more engaging and impactful, resulting in a higher level of knowledge among the respondents.

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A review: Indian innovations in millet-based extruded products

N. D. Joshi^{*1}, S. H. Akabri², G. H. Athawale³, Meetkumar Thakar⁴ and G. S. Dave⁵

¹College of Food technology, SDAU, Sardarkrushinagar

²College of Food Technology & Bio-energy, AAU, Anand

³MIT School of food technology, MIT Art, Design & Technology University, Pune

⁴Department of Applied Chemistry, Faculty of Technology and Engineering,
The Maharaja Sayajirao University of Baroda, Vadodara

⁵Bio Science Research Centre, SDAU, Sardarkrushinagar

*Email: niravjosshi56@sdau.edu.in

ABSTRACT

Millets are an important crop for most of them of farmers with small land holdings in terms of agricultural practises, health and nutritional security, and climate change. These days, many prefer extruded snacks over conventional ones, especially when they are ready to consume. Most commercially available snacks are mostly made of cereal, which is a decent source of carbs but deficient in protein and other minerals like iron. For this reason, it's critical to change the ingredients used to produce snacks in order to provide balanced nutrients like minerals and protein. Millets are the least priced and highest protein grain, thus using them will address this problem. Thus, an endeavour was made to develop a snack based on millet by combining several types of millets, such as sorghum, oats, and green gramme, and investigating the characteristics of these millets. Extrusion is a versatile, cutting-edge technique that has the ability to significantly alter how food ingredients work in order to improve digestibility and sensory quality. The food enterprise, scientists, and processors/consumers may select the optimal processing technique to maximise nutritional content, increase nutrient bioavailability, and support nutrition security by having a better understanding of how processing impacts millets' nutrient content. In this study, we focus on recent developments in the production of millet and pulse-based extruded foods. Additionally, the use of extruded flours as novel, environmentally friendly ingredients-such as hydrocolloids and fat substitutes-as well as for the creation of gluten-free, phenolic-rich, low-glycemic, and functional meals has been examined.

Key words : Millet, Extrusion, Nutritional benefit.

INTRODUCTION

In the realm of agriculture and nutrition, millets have emerged as a vital crop, offering solutions to various contemporary challenges such as climate change, health and nutritional security, and sustainable agricultural practices, particularly for modestly sized farmers with small land

holdings (Chotonet *al.*, 2020; Navaleet *al.*, 2015; Shelaret *al.*, 2019). In today's fast-paced world, the preference for extruded snacks, particularly those that are ready to eat, has seen a significant rise. However, many of these snacks are primarily composed of cereals, rich in carbohydrates but lacking in essential nutrients like protein and minerals, such as iron. This nutritional

imbalance has raised concerns regarding the health impact of popular snack choices (Bordoloi *et al.*, 2014; Kumare *et al.*, 2018). The solution to this dilemma lies in reimagining the raw materials used in snack production to ensure a balanced nutrient profile, rich in protein and minerals. Millets, with their remarkable affordability and high protein content, offer a promising alternative. A concentrated effort has been made to develop millet-based snacks in answer to this requirement, utilising a variety of millet combinations, such as sorghum, oats, and green gram (Amadou *et al.*, 2013; Chandra *et al.*, 2016; Taylor *et al.*, 2006). These creative concoctions aim to maximise the inherent properties of these hardy grains, abundant in nutrients and adaptability. (Azmi *et al.*, 2013; Taylor *et al.*, 2008). The process of extrusion, a dynamic and inventive technique with enormous potential to improve the digestibility and sensory quality of food ingredients, is essential to this transition. Researches and customers alike must comprehend how processing methods affect the nutritional value of millets in addition to the food sector. (Assadpoure *et al.*, 2019; Mohammed *et al.*, 2020). It enables informed choices in processing methods that maximize nutrient retention and bioavailability, ultimately contributing to improved nutrition security (Jaybhaye *et al.*, 2014; Kumare *et al.*, 2021). This review delves into recent advancements in the production of extruded products, crafted from the bounty of millets and pulses. Additionally, the exploration of extruded flours as innovative green components, serving as hydrocolloids, fat substitutes, and as a foundation for the creation of gluten-free, phenolic-rich, low glycemic, and functional meals, underscores the multifaceted potential of these ancient grains (Kumar *et al.*, 2018; Pasqualone *et al.*, 2020). As we embark on this journey through

the realms of millet-based snack production and extraction techniques, we uncover not only a realm of nutrition-enhancing possibilities but also a pathway to a more sustainable and wholesome future in food innovation (Arribas *et al.*, 2017; Choton *et al.*, 2020).

Process flow for various millets based extruded products

Various millets-based extruded products have gained prominence in the food industry due to their nutritional benefits and versatility. The production of these extruded products involves a combination of extrusion technology and the unique characteristics of different millets. Here are a few methods for making extruded items made from millets:

Extrusion technology for various millet based products

The food industry can use modified extruded flours for a variety of purposes, including thickening, gelling, functional additives, and fat replacement (Mohammed *et al.*, 2020; Saini *et al.*, 2021). The processing of wheat, corn, and rice flours for the creation of ready-to-eat snack goods has made extensive use of extrusion cooking. From a nutritional perspective, they are paradoxically heavy in fats and carbohydrates and low in dietary fiber, which results in a high glycemic load. This is well recognized to induce type 2 diabetes and pediatric obesity (Arribas *et al.*, 2017; Burešová *et al.*, 2017).

To qualify as functional foods, snacks must be enhanced with high levels of protein, dietary fiber, minerals, and phenolics. Using organically derived food items like pulses, whole grains, millets, pseudocereals, and other items is a great way to create useful snacks. Millets have favourable outcomes on blood lipids and glucose, reduce the possibility of cardiovascular disease and several malignancies, and enhance insulin resistance (Kaure *et al.*, 2014). As a result,

millet is a great way to add more nutritional fiber to prepared foods. To increase the amount of dietary fibre in extruded goods at a lower cost than adding purified fiber, millet flours can be used. (Wojtowicz *et al.*, 2015).

Using components made of extruded flours aids in the management of type 2 diabetes and the glycemic response. Extrusion processing is one way to modify starch digestibility, and it is believed to be a major factor in modifying the glycemic response. Regarding the starch digestibility of extruded items, there are now two opposing theories that are generally acknowledged. As stated by the first theory, foods that are extruded fall under the high glycemic index (GI) food category. (Onwulata *et al.*, 2010). This depends on the finding that starch fragmentation and partial gelatinization (Cabrera-Chavez *et al.*, 2012). Proteins with altered structures and conformations are often more digestible. Because the depolymerization process makes starch easier for amylolytic enzymes to access during digestion, extruded snack items frequently have a greater glycemic rather than their unfiltered, unprocessed component equivalents. On the other hand, the second idea classifies them as low GI foods. This is due to the fact that extrusion also alters the starch's structure, producing less substantial amylose and amylopectin units that may combine to form new, indigestible bonds and lower the GI. (Liu *et al.*, 2015). Strong evidence points to the formation of amylose-lipid complexes in these processes.

Effect of various processing methods

Given the threat to global food security, it is imperative that we make effective use of the millet crops that are now accessible to produce a nutrient-rich, aesthetically pleasing, and reasonably priced product. To separate the unsuitable portions and

transform the millet grains into cooked and consumable form, processing is required. Processing is consequently necessary since it increases the absorption of vitamins and minerals and their organoleptic compounds characteristics while reducing antinutrients. There are two types of processing that can be done: principal and secondary. Primary processing involves removing anti-nutritional elements and unwanted seed coat through cleaning, soaking/germination, de-hulling, milling (to make flour and semolina), and refining. Secondary processing involves using flaking, popping, extrusion, and baking to turn primary processed raw materials into "ready-to-cook" (RTC) or "ready-to-eat" (RTE) products. (Rao *et al.*, 2017).

De-branning, milling, roasting, soaking, steaming germination, popping, flaking, salted grains that are ready to eat, and fermented goods are examples of traditional processing techniques.

The goal of these processing methods is to transform grains into consumable forms that have better texture, taste, and unique flavor as well as increased digestibility and nutritional value. (Yousaf *et al.*, 2021). Processing millet into different by-products can boost its consumption and use while lowering its levels of phytate and tannin, increasing the bioavailability of minerals and amino acids, and improving the digestibility of starch and protein. (Deshpande *et al.*, 2015).

These bioactive substances found in entire grains undergo particular physiological, structural, or altered consequently of processing. The processing methods may have both positive and negative effects on the nutritional and anti-nutrient composition. Numerous investigations on millet Studies have demonstrated the benefits of using millet in a range of conventional and quick-to-prepare nutritious foods. Trypsin inhibitors, tannins, phenols, and significant amounts of

phytates reduce the quality and absorption of nutrients, preventing millets from reaching their full nutritious potential (Rao *et al.*, 2017). Because some millets have larger levels of fats that aren't saturated than others, sourness and off tastes can develop in millet flour over time as consequently of lipolysis and oxidation of "de-esterified fatty acids." (Bora *et al.*, 2019). To allow millet to be used effectively, it is crucial to comprehend how processing affects their nutritional qualities. It also helps in selecting the right processing method for millet to be able to enhance palatability, optimize nutrient availability, and lengthen shelf life (Gowda *et al.*, 2022).

DISCUSSION

Extrusion Technology

In the 1870s, extruders were created to produce sausage. The 1930s saw the development of the single-screw extruder, which was used to combine semolina flour with water to create pasta products. It was also used to mold hot, precooked dough for the production of ready-to-eat (RTE) cereals. The amount of shear rate was minimal in each of these situations. Directly expanded maize curls were made in the late 1930s and early 1940s with extruders, which had very high shear rates. In the middle of the 1950s, the first patent application utilising twin-screw extrusion technique was submitted. Since then, there has been a significant advancement, expansion, and growth in the use of extrusion technology in food processing. (Rao *et al.*, 2015).

Five major components make up an extruder: the die and cutting mechanism; the barrel; the screw or worm; the feeding system; the pre-conditioning system; and the barrel. Regarding screw, barrel, and die configuration, they might differ. The choice of

each of these products will rely on the intended end result and the raw material utilized. (Riaz, 2000).

The basic principles of extrusion involve feeding raw ingredients into the barrel of the extruder, followed by the screw (s) that move the food along it. Smaller flights further down the barrel limit the volume and heighten the food's resistance to movement. It becomes squeezed as a result of filling the barrel and the gaps between the screw flights. The material is worked by the screw into a semi-solid, plasticized mass as it travels down the barrel. Extrusion cooking, sometimes referred to as hot extrusion, is the method of heating food beyond 100°C.

The food industry can use modified extruded flours for a variety of purposes, including thickening, gelling, functional additives, and fat replacement. The potential of extruded flours as functional snacks, morning cereals, and additions in millet-based extruded goods has been critically highlighted in recent publications. Using extrusion to create useful treats the processing of wheat, corn and rice flours for the creation of ready-to-eat snack goods has made considerable use of extrusion cooking. From a nutritional perspective, they are paradoxically heavy in fats and carbohydrates and low in dietary fibre, which results in a high glycemic load. This is well recognized to induce type 2 diabetes and paediatric obesity.

The glycemic index of morning cereals made via extrusion can be lowered by using non-traditional cereal flours like amaranth, buckwheat, or millet, according to recent study articles. Higher bulk and product density, a comparable expansion ratio, and "a significant reduction in readily digestible carbohydrates and slowly digestible carbohydrates" are all present in the extruded made utilizing these grain flours. According to another study, "the rate and

extent of carbohydrate hydrolysis of the extruded products" is significantly reduced when dietary fibre is added to the extruded breakfast cereal mix in place of 5% to 15% of wheat flour and white flour. This increases the amount of slowly digested carbohydrates and decreases the amount of quickly digested carbohydrates.

Using extruded flours as components helps control type 2 diabetes and the glycemic response. Starch digestibility may be adjusted by extrusion processing, and this is thought to be a key component in adjusting the glycemic response. There are now two competing ideas that are widely accepted about the starch digestibility of extruded goods. According to the first idea, foods that are extruded fall within the high glycemic index (GI) food group. This is predicated on the observation that protein structural and conformational alterations, as well as partial gelatinization, often enhance overall digestibility. When starch is depolymerized, it becomes easily accessible to amylolytic enzymes during digestion. As a result, extruded snack items often have a greater glycemic response than their raw, unprocessed component counterparts. Conversely, the second idea classifies them as low GI meals.

To be considered functional foods, snacks must be enhanced with high levels of protein, dietary fibre, minerals, and phenolics. An advantageous time to make functional snacks is when whole grains, millets, pulses, pseudo cereals, and other organically derived components are used. These days, pulses are regarded as useful gluten-free grains with high nutritional fibre content and complex carbs, which results in a low glycemic index in extrusion formulations. The evaluation of pulses (soybean, chickpea, beans, peas, lentils, etc.) for extruded snacks has received a lot of attention in recent years.

Extruded pulses are thought to be very viable for the production of high-nutrient, low-calorie snacks with additional value because of reports of their excellent growth. Millets have positive effects on blood lipids and glucose, reduce the risk of cardiovascular disease and several malignancies, and enhance insulin resistance. As a result, millets are a great way to add more nutritional fibre to prepared foods.

To increase the nutritional fibre content of extruded goods at a lower cost than adding purified fibre, millet flours can be used. Healthy food enthusiasts can find natural fruit or vegetable colours in extruded items appealing. Here, natural colours have been added to dried fruit powders high in anthocyanins and carotenoids to enhance the colour appeal and overall antioxidant benefit of extrudates.

This is because extrusion also modifies the structure of starch, resulting in smaller amylose and amylopectin units that may cross link to generate new, indigestible connections and reduce the GI. Strong evidence points to the formation of amylose-lipid complexes in these processes. Numerous variables, including the degree of starch gelatinization, the kinds of native crystalline structures, the ratio of amylose to amylopectin, and the development of complexes between starch and lipid or protein or resistant starch, influence the GI of starch-based foods that are extruded.

Short-duration, high-temperature extrusion "minimises losses in vitamins and amino acids". Some foods may be produced in large quantities using extrusion, which also "denatures anti-nutritional factors" including poisons and microbes. It also has an impact on the product's form, texture, colour, and flavour, and may enhance "protein quality and digestibility". Moreover, it may break down proteins, starches, and non-starch

polysaccharides to produce "reactive molecules that may form new linkages not found in nature." This includes Maillard processes, which lessen the proteins' nutritious content. Heat-labile vitamins might be damaged. Moderate circumstances (short time, high moisture, low temperature) have been reported to increase nutritional quality

CONCLUSION

Milletts are comparable in energy content to ordinary grains. They are rich in fibre, minerals, vitamins, macro- and micronutrients, and phytochemicals. They can help cure chronic conditions and provide more significant health benefits. Prepared millet is an economical, filling, and beneficial dinner option when incorporated into a daily diet. It was discovered that during germination and fermentation, the nutritional fibre, mineral, and vitamin contents of the majority of millets rose. In the fight against protein-energy malnutrition, straightforward processing techniques including soaking, germination/malting, and fermentation can boost protein digestibility and increase mineral absorption. Considering the range of ways that processing alters the nutritional properties of millets, attention ought to be focused on refining the techniques for processing smaller millets in order to boost their appeal while preserving their health advantages. Based on the reviewed literature, it is reasonable to conclude that extrusion is a very flexible and promising technology, and that it should be seen more widely as a groundbreaking way to produce better functional meals that go beyond the usual extruded snack alternatives. Extrusion offers a wonderful technique to modify the hydration properties and improve paste stability and food matrix performance by varying the processing settings.

The barrel's temperature and pressure, the die aperture diameter, and the product shear rate are critical operational parameters. The speed and geometry of the screw (the size, quantity, pitch, and diameter of the flights) as well as the internal barrel design, which includes grooves or limitations (referred to variously as "throttle rings," "kneading discs," or "shearlocks"), all have an impact on the shear rate. A steam-jacketed barrel, a steam-heated screw, or electric heating components around the barrel can all offer further warmth.

Extrusion has "revolutionised many conventional snack manufacturing processes" and made it possible to produce new processed food items. Extrusion produces a variety of food items, most of which have a high starch content. Corn curls and morning cereals are examples of directly expanded forms that are produced under high shear, low moisture and high temperature circumstances. Pasta is an example of a non-expanded product; it is made at a low temperature and an intermediate moisture content (about 40%). Fish paste and meat analogues, which are produced with "textured vegetable protein" derived from plants and a lengthy die to "impart a fibrous, meat-like structure to the extruded," are examples of items that have been texturized. Candy produced by extrusion includes licorice, toffee, and chewing gum. Some breads (such as croutons, bread sticks, and flat breads), other ready-to-eat snacks, pre-made cookie dough, some infant meals, some drinks, and dry and semi-moist pet foods are among the other food items that are frequently manufactured by extrusion. Macaroni, jelly beans, sevai, and certain french fries are some specific examples. Additionally, extrusion is used to pellet animal feed and alter starch.

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