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Reducing Ecological Footprints by Substituting Animal Protein in Indian Diet

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A B S T R A C T

Food provides daily nourishment and energy required by human body. In Indian diets, most of the protein is supplied by plant sources rather than non-vegetarian foods. But unfortunately, this does not meet the Recommended Dietary Allowance. Though non-vegetarian foods are good sources of proteins, farming and rearing of livestock increases carbon and water footprint. Carbon emission and production of greenhouse gases are inevitable during the whole process of cultivation, farming and processing of food. Water is also required during these activities. While producing a simple meal, the environment is affected as considerable amount of greenhouse gasses are generated and natural resources are utilized. For non-vegetarian foods these effects are multiplied many times. Switching to plant-based food can reduce both. Use of textured vegetable protein is already in practice and other plant protein sources like pulses are being utilized for creating substitute for egg, milk etc. Macroalgae and lab engineered protein are areas of research for future protein sources in diets. While planning a meal, controlled and sustainable use of natural resources is advised for benefit of the environment and mankind. This research paper is an approach for suggesting suitable protein alternatives for sustainable and futuristic diet plan by reducing carbon and water footprint.

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INTRODUCTION

As per United nations data, world population is increasing at a steady rate. At present it has just crossed 8 billion (https://www.worldometers.info/world-population/). It is expected that by 2060 the figure would exceed by 25% and cross 10 billion. (***Table 1***). To support such level of population, human race should be equipped with enough amount of agricultural land for cultivating required amount of food. At present, according to 'OurWorldinData.org', (https://ourworldindata.org/global-land-for-agriculture) almost half of the habitable land is being used for agriculture. (Ritchie, H., 2019). But out of that almost 77% area is being used for livestock & only 23% for crops. These crops provide 82% of the required energy. (***Figure 1***).

Table 1 : World Population Prediction

Year (July 1)	World Population	Yearly % Change		Year (July 1)	World Population	Yearly % Change
2020	7,794,798,739	1.10 %		2045	9,481,803,274	0.61 %
2025	8,184,437,460	0.98 %		2050	9,735,033,990	0.53 %
2030	8,548,487,400	0.87 %		2055	9,958,094,074	0.43 %
2035	8,887,524,213	0.78 %		2060	**10,151,448,761**	0.36 %
2040	9,198,847,240	0.69 %				

Data Source : https://www.worldometers.info/world-population/

To meet the food & energy requirement of 10 billion people, the pattern of land use should be modified. Other alternatives and additional solutions should also be explored. Enhancement of feeding capacity for future population, will also invite extra load on carbon & water footprint. Care should be taken to balance the requirement & sustainable consumption of natural resources to protect both – the human race & the environment.

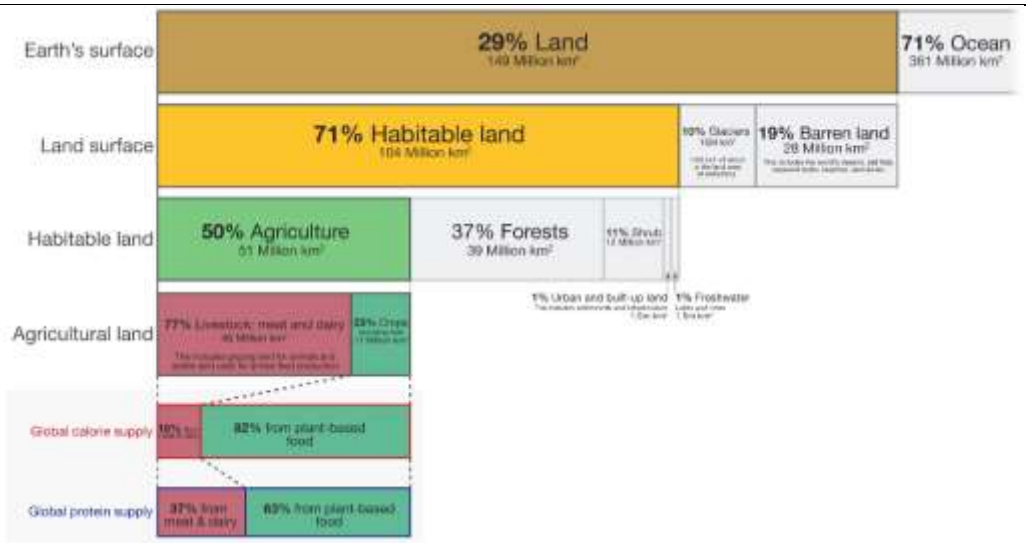


Image source : https://ourworldindata.org/global-land-for-agriculture

Figure 1 : Global land use for Food Production

THEORETICAL REVIEW

Factors like climate change, population boom, land use conflict, rising health issue cost are some of the reasons which make contemporary food production and consumption pattern unsustainable. Industrialization and globalization in the field of agriculture and food processing along with the shift of consumption patterns towards more dietary animal protein, the emergence of modern food styles that entail heavily processed products sounds very promising, but in the long run challenging for overall benefit of mankind and the environment. (Reisch, L. et al 2013).

METHODOLOGY

Quest for an alternative & sustainable food for future is a subject of global concern. This research paper is an approach for finding out suitable substitutes for many popular common foods having high carbon & water footprint with products having lower carbon emission and less water consumption during production. While selecting ingredients for diet, factors like taste, nutritive value, ease of use, and availability should be considered. Beside these, economic factor is also to be considered as prime determinant. Advancement in the field of food technology has opened avenues for new options in ingredient selection. One can find a variety of choices on the shelves of departmental stores to satisfy the nutritional requirements with plant-based food items. Identifying the combination of plant-based protein substitute in preparing everyday meal requires knowledge & experience in the field of gastronomy and modern food technology. A Chef can identify the requirement of the consumers and decide on the selection of environment friendly sustainable ingredients for providing a standard meal as per the recommended guidelines.

Data Collection

Online survey through questionnaire was conducted used to collect primary data find out the general food habits of Indians across different demographic parameters. There are 139 responses in the survey which suggested with valuable information in the related field. Secondary data were collected from various research papers, websites, articles, newspaper & magazines. Beside these, informal interviews with several persons of varied backgrounds also provided relevant information which are found to be useful for meeting the objectives of this research paper.

Objective

- To understand importance of low carbon & water footprint in our diet
- To compare carbon & water footprint of plant & animal food sources
- To find out different acceptable substitutes for animal proteins in developing a sustainable diet.

RESULT AND DISCUSSION

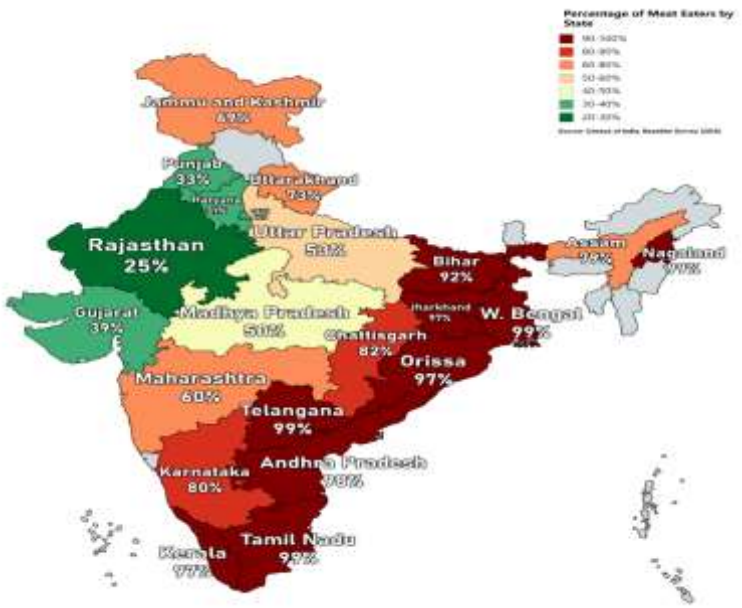
Carbon & water footprints are major areas of concern at present days. Production and processing of food are responsible for emission of greenhouse gases (GHG). According to research and data available in

'OurworldinData.org', 25% to 30% of global greenhouse gas emissions come from food. Considering all other agricultural products, it is about one-third of the total global emission. (Crippa M. et al 2021; Poore, J., & Nemecek, T. 2018).
For diminishing carbon footprint and water footprint, similar types of policy responses are developed. Many common terms are used in both the fields, like 'reducing', 'efficiency', 'offsetting', 'neutral', 'capping', 'permits', 'labelling' etc., all of which are used for setting a control on the consumption level of various commodities & services. (Ercin, E., & Hoekstra, A. Y., 2012).

In India meals are rich in carbohydrate from where the energy is obtained. Intake of fats & oils is monitored, but daily protein requirement is neglected. Though we focus on satiety and energy from food, nutritional balance is mostly overlooked if not suggested by professionals. Even nutritional imbalance is common with many economically sound families. Effects of nutritional imbalance is noticed on our health as we age. Designing an alternative food is a complicated task. While redesigning diet, one should focus on factors like nutrients, flavour, ease of digestion, assimilation, and finally production cost. Ease of availability of raw material is also to be considered. Flavour (combination of taste & aroma) should be given special emphasis as it plays the main role in making the food popular.

Food habits in India

India has diverse food habits due to various reasons. Statistics shows that state-wise non-vegetarian food consumption follows a noticeable pattern. (***Figure* 2**). States in the North-Western region are more vegetarian than states of South-Eastern region. Survey revealed that states like Punjab, Gujrat, Haryana, Rajasthan etc. have nearly 30% non-vegetarian population whereas Kerala, Tamilnadu, Telengana, Andhra Pradesh, Orisha, Bengal and North-East states have more than 90% of non-vegetarian population. In general, consumption of egg & chicken is comparatively more compared to mutton & fish. (***Figure 3***).



Source : Census of India, Baseline Survey (2014)

Figure 2 : Non-vegetarian Food Consumption in India

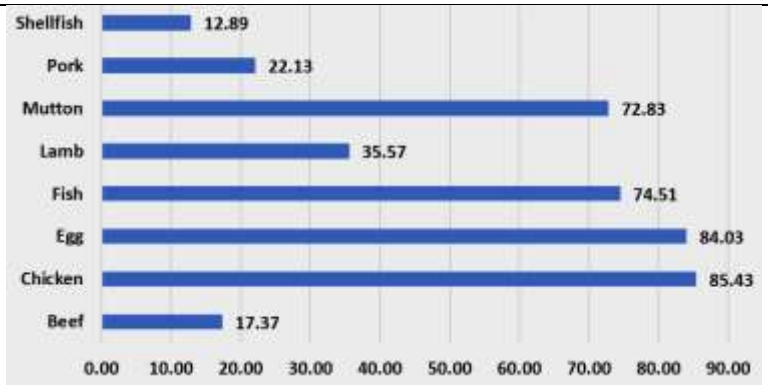


Image Source : Survey Data

Figure 3 : Popularity of Non-vegetarian Food

The survey results indicate that weekly consumption of non-vegetarian food per capita is inadequate considering standard serving quantity. (***Figure 4***). It is difficult to meet the daily requirement of protein from such a diet plan if not properly supplemented.

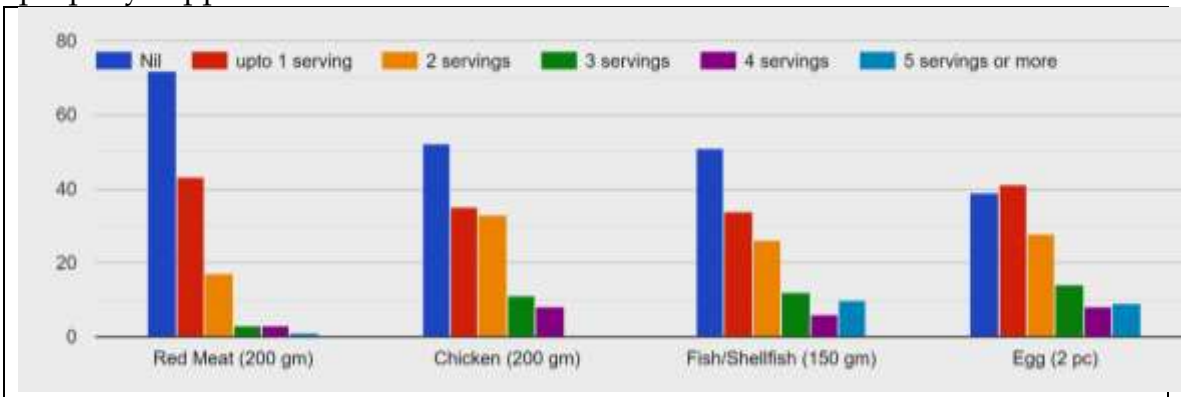


Image Source : Survey Data

Figure 4 : Per head consumption (serving quantity as mentioned) in a week

Meals are focused on vegetarian food, generally influenced by religion and culture. Taste varies on regional basis & religion controls on the selection of the food ingredients, especially non-vegetarian items. Meals are composed of vegetables, cereals, pulses, fruits and dairy. Non-vegetarian items appear in the menu in cyclic order and sometimes only once in a week. Most of the protein comes from cereals and found to be insufficient for the body. (Saxena, A., 2016). Focus should be given on various types of pulses as an immediate remedy. Plant based foods and substitutes can remove religion related barriers & prohibitions for different non-vegetarian provisions.

Carbon Footprint

Carbon footprint is the total amount of greenhouse gases we produce by different activities, for our survival. Carbon footprint can be measured by weight per time or per unit weight of a product. Beside carbon dioxide (CO_2) & methane (CH_4), other greenhouse gases like nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) were identified in Kyoto Protocol (1997) as the prime reason for global warming. (Iwata, H. et al, 2014). These gases are very high in Global Warming Potential (GWP). (***Figure 5***). By taking small steps in changing our lifestyle, we

can produce less of GHG, thus reduce carbon footprint. Simple activities like consumption of less meat, and animal products, walking and cycling instead of using other vehicle, taking stairs, line drying clothes etc. are very common examples.

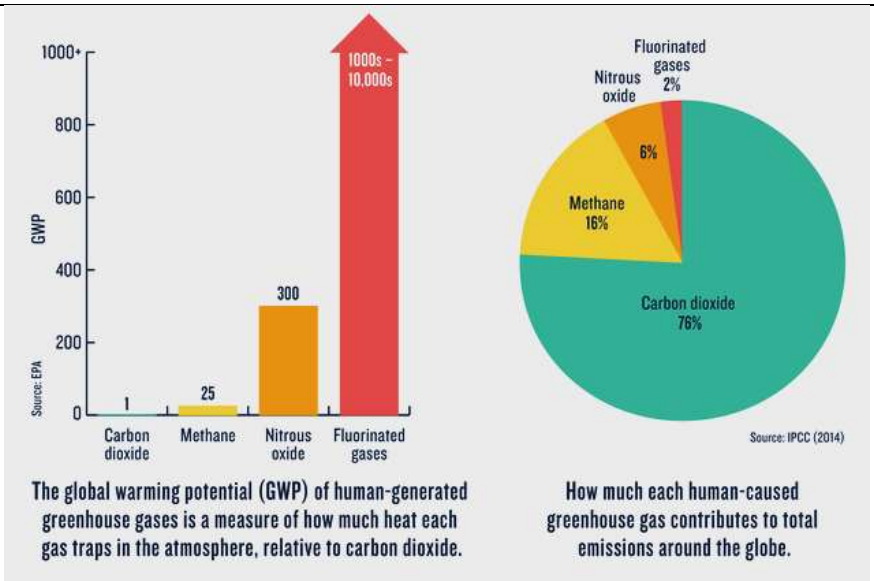


Image Source : https://www.nrdc.org/stories/greenhouse-effect-101

Figure 5 : Effect of Greenhouse Gasses

Water Footprint

The water footprint of a product is an empirical and multidimensional indicator of use of fresh water for its production. Water footprint of a food ingredient is the amount of fresh water required for producing unit quantity of the item. While calculating water footprint, the total requirement of various types of fresh waters in different stages of production is to be considered. Even it should include the indirect requirements during transportation phases. Thus, actual water footprint of an item can be calculated, if the producer and the final consumer are identified. Hence, for the same product, water footprint may differ depending on the location of the producer and the consumer. (Mekonnen, M. M., & Gerbens-Leenes, W., 2020).

Natural sources of fresh water include mainly blue water & green water. (Water Footprint Network, https://waterfootprint.org/en/).

- Blue water is the fresh water available freely in nature, like on earth surface or in underground aquifers. This is used for drinking, domestic purpose, or industry & commercial requirements. We can use it for irrigation also.
- Green water refers to the water which is absorbed in the soil and mostly used by the plants. Green water in the soil is recharged by rainfall or snowmelts. Beyond the absorption by the soil, the excess amount of rainfall is generally stored in water reservoirs.
- Grey water is manmade and mostly recyclable. It is the wastewater produced from kitchen, laundry etc. but not from bathroom. Depending on the pollutants, grey water should be treated and used for specific purposes. Care should be taken, so that it can be used to support environment instead of polluting it. Black water, which comes out from

the bathroom, contains pathogens, should be treated properly and discarded.

While calculating water footprint of a food product, several factors get involved. Geographical location, nearby water source, climatic condition, species, use of feed and fertilizer, and finally intermediate processing. Transportation also contributes a lot on the water & carbon footprint. Beside all the mentioned factors, different methods of calculating water footprint give confusing results. (Chenoweth, J. et al, 2014). But considering all the statistics, it is established that water footprint for plant sourced food products is much less than animal products. (Pathak, H. et al, 2010).

Worldwide empirical study revealed that crop commodities have low CO_2 emission contribution compared to livestock products or manufactured food. Pathak, H. et al have indicated in their research paper (2010) that changes in food habit may reduce GHG emission. Food items with less carbon footprint would have better impact on the environment.

To reduce carbon & water footprints we can decrease non-vegetarian item consumption, switch to substitutes for meat, egg and milk. Selection of local food can also be effective. But during such changes one should not neglect the nutritional factor of the diet. Proper study should be done to ensure supply of all the nutrients required for the body. The meal plan should be area specific. Special consideration should be given taste factor. A nutritional diet, lacking taste would not be accepted by the consumers. While selecting the food ingredients & substitutes, we should ensure, not to compromise with the taste of the dish.

Switching to a new type of sustainable food leaving the conventional food is a difficult task. However, this can be achieved in community level by systematic long-term approach in the society. Creating awareness, approaching through friends & relatives, accessible pricing, health benefits etc. can develop interest among the potential consumers. (Hsu, S. Y. et al. 2020; Grunert, K. G., 2011).

Protein

Proteins, made of Amino acids, are building blocks for our body, and the recommended dietary allowance (RDA) to prevent deficiency for an average sedentary adult is 0.8 grams per kilogram of body weight. (Pellet, P. L., 1990; Traylor, D. A., et al, 2018). Amino acids required for human body are classified as Essential amino acids, Nonessential amino acids and Conditional amino acids.

Essential amino acids are those amino acids which cannot be synthesized within our body and should be sourced from food. There are 9 essential amino acids which are - histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. Nonessential amino acids are synthesized within our body. Conditional amino acids are required during specific conditions of our body like illness.

All types of proteins are not suitable for assimilation in human body. Nutritional benefits of a protein depend on the quality of the protein, which is determined by assessing its essential amino acids, digestibility and

bioavailability of amino acids. Out of many measurement scales and techniques, Protein Digestibility Corrected Amino Acid Score (PDCAAS) is accepted by FAO/WHO in 1990. In this method the amino acid requirements of humans and their ability to digest are taken into consideration. (Hoffman, J. R., & Falvo, M. J., 2004).

Protein from animal sources contains all the essential amino acids. In India, even the non-vegetarian people do not consume enough amount of protein as per recommendation. In general, protein deficiency is noticed in all age groups. For the vegetarian people, the situation is more serious. Most of plant sources do not supply all the essential amino acids. Hence for a vegetarian diet, combination of various plant sources for proteins is recommended. The deficiency situation for both the groups can be addressed by supplying extracted protein from different plat sources. For this purpose, plant protein can be extracted by the methods like Crude extraction, Centrifugation, Dialysis, Column chromatography, Gel-filtration, Ion-exchange, Microwave, High pressure, Osmotic shock, Ultrasonic treatment, Enzymatic hydrolysis purification, etc. The methods can be chosen depending on the characteristics of the protein sources like solubility, size, binding specificity etc. Beside all these factors, cost of extraction also is one of the prime determinants.

While extracting protein from plant sources, the external factors should be controlled as per the source. The factors include p^H value, temperature, pressure and additives. The additives include salt, enzymes, solvents etc. A p^H value near 7 is considered ideal, which can be obtained by using various biological buffers like Phosphate, Tris, MOPS, HEPES etc. (Hicks, M., & Gebicki, J. M., 1986; Boivin, S., et al, 2013). Control of temperature during protein extraction is also a crucial factor. Plant protein extraction should be done at a very low temperature like 4^oC, whereas from mammalians and bacteria it can be around 37^oC. (Oreopoulou, V., & Tzia, C., 2007; Kumar, M., et al, 2021; Conlon, H. E., & Salter, M. G., 2007; Helstad, A., et al, 2022).

Choice of plant protein based non-vegetarian identical products are highly promising and on the demand. Moong protein can be made identical to egg products, and similarly soy extract can replace milk, pea protein can be used for making cheese substitute.

Textured Vegetable Protein (TVP) or Structured Meat Analog (SMA)

Textured Vegetable Protein (TVP) also known as Structured Meat Analog (SMA) is prepared from plant protein, mainly from soybean. Protein from other sources like wheat, oats, corn, cottonseed, peanut, etc. can also be texturized. (Featherstone, S., 2015). TVP can be prepared from the high protein rich remaining part of the soybean after the oil is extracted in solvent method. (Serrato, A. G., 1981). The high-protein & low-fat by-product is checked for required moisture content and mixed with other desired ingredients. To achieve a chewy finish, with meat like fibrous texture, high moisture content of 50%-70% should be maintained. But for items resembling sausage, 20%-30% moisture is sufficient. The mixture is passed through a twin-screw extruder and cooked under pressure. While coming out of the extruder die, the product expands and gets the shape of textured vegetable protein resembling meat.

When properly cooked, such meat analogues can absorb almost 3 times water of their weight. Cooked product looks similar to meat in appearance & texture. When chewed, it also gives meat like mouthfeel. SMA can be shaped as per choice to resemble various types of meat. Natural or artificial food colours may be added to mimic the appearance of cooked red meat or cured meat. (Riaz, M. N., 2011).

Macroalgae (Seaweeds)

Macroalgae or seaweeds are good source of nutrients. These are rich in proteins, vitamins, minerals. They are also having high proportion of essential fatty acids like EPA & DHA. Macroalgae are classified as green, brown and red as per their colour. There are thousands of species available. Till date about 4000-6000 species of red, 1500-2000 of brown and around 4500 of green seaweeds are identified. Marine macroalgae (seaweeds) are found in different depths. Red species grows where less sunlight reaches whereas green & brown develop in littoral zones. Composition of the macroalgae also influenced by local conditions at the collection site, such as light, salinity, nutrients, temperature, pollution and water motion etc. (Gordalina, M., et al, 2021).

Macroalgae are rich in protein and in some cases, it (red variety) contains up to 47% of dry weight. These are good sources of all the essential amino acids needed for human nutrition. But extracting protein from the seaweeds is difficult due to the complex nature of the cell wall which the human gastrointestinal enzymes are unable to break down. However, research is going on to counter this problem and the results are very promising. Combination of various chemical & physical methods are used for extraction. (O'Connor, J., et al, 2020; Bleakley, S., & Hayes, M., 2017).

Taste enhancement by Fermentation

Inclusion of textured protein or macroalgae in diet would require further treatment so that they can be blended well with other ingredients. Controlled fermentation increases glutamate (Maslami, V., 2018) and develops umami taste of the food making it 'more meaty'. During production, fermentation can impart the meaty flovour in textured vegetable protein to make it a real meat substitute. (Steinkraus, K. H., 1994). Recent research on fermentation in TVP production using *Bacillus subtilis* is found to be highly promising. (Gu, B. Y., et al., 2020). Fermentation can also increase the nutritional value and/or digestibility of food. Some microorganisms can increase the levels of several bioactive compounds like vitamins, antioxidant compounds, peptides, etc. Bioactive compounds are molecules present in small quantities in foods that provide health benefits beyond the basic nutritional value. Fermentation of macroalgae helps in extracting the nutrients and also improve the taste to make the product palatable and acceptable to wide range of consumers. (Mallick, H. N., 2007; Sano, C., 2009; Pathak, H., et al, 2010; Jinap, S., & Hajeb, P., 2010; Vandenbeuch, A., & Kinnamon, S. C., 2016; Verardo, V., et al, 2020; Pérez-Alva, A., 2022).

Lab Engineered Proteins

Lab engineered proteins has opened new avenue to meet the demand for proteins in the meal. Protein from peas, *moong dal*, etc. are restructured to

resemble vegan egg & dairy products. Some producers like Tyson, Memphis Meats are manufacturing plant-based meat substitutes in the lab. Animal stem cells are cultured and multiplied in lab to generate meat products. This not only reduces the load on the environment and cruelty against the animals, but also can regulate the price of the 'meat products'. (Tay, C., 2018).

CONCLUSIONS

'EAT-Lancet reference diet' guides about planning a diet which is healthy for human & sustainable for the environment. In present days, for Indians, across all demographic factors, nutrition is compromised. In India it is noticed that major part of the required calorie comes from cereals. To plan a healthy diet, in India, production pattern is to be reviewed & redesigned. Cultivating more of coarse cereals and pulses can change the food consumption pattern in India towards a healthy one. Within each type of food category, there may be huge differences in ecological footprints. Some vegetables & fruits score high compared to others. In off-season, vegetables & fruits require more resources to grow than in season. Cultivation of seasonal & local vegetables would be more sustainable environmentally & economically. For these transformations, to address malnutrition and saving the environment, an integrated approach is required which would include areas like agriculture, trade, consumer awareness etc. (Sharma, M. et al, 2020).

For non-vegetarian people, it is difficult to give up meat products totally from diet, but by switching from beef, lamb or pork to chicken can reduce substantial amount of carbon footprint. Noticeable reduction in ecological footprints may be observed by switching over to fish and chicken from red meat. Naturally grown fish has negligible ecological footprint compared to farmed fish. (Yuan, Q., et al, 2017). Vegan diet may be considered a better solution for reducing both carbon & water footprint. (Alexander G., 2022).

While focusing on the ecological footprint, one should not neglect nutritional aspects in the diet. Research is going on in this field and many of the solutions are really promising like – new food sources, change in cultivation pattern, food from ocean, fortification of existing food, substitution with plant products etc. Less processed ingredients should be chosen as processing increases both carbon and water footprint.

FURTHER STUDY

To support the environment by providing sustainable food is a real-life and real-time challenge. Avoiding animal protein and switching to plant based one, is difficult for consumers to accept. Beside long nurtured habits, taste is considered as prime factor. Nutritional aspects come next. New products with suitable alternatives from different companies are available in the market. Still there is enough scope of improvement on nutritional factor and taste. Research in this field is a continuous process and recommended.

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