RECENT ADVANCES AND PROSPECTS IN PALAK(*Beta vulgaris* var. *bengalensis*) AND SPINACH(*Spinacia oleraceae)*

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ABSTRACT

Palak scientifically known as *Beta vulgaris* L. var. *bengalensis Hort*. Is considered to be the most common and important leafy vegetable which is mainly grown in tropical as well as sub tropical regions. It is a member of Chenopodiaceae family and known by other names such as leaf beet, beet palak, Indian palak *etc*. in different regions of India. Spinach (*Spinacia oleracea*) is a diploid (2n = 2x = 12), wind-pollinated and highly heterozygous crop. The plants are mostly dioecious, although some monoecious plants exist. Spinach is an economically important cool-season leafy vegetable crop. Demand for spinach is increasing worldwide, particularly due to its high nutritional content. Palak and spinach is a versatile crop eaten raw or cooked and used as salads or mixed with other cuisines.

Keyword: Recent advances, palak, spinach, *Beta vulgaris, Spinacia oleraceae*, green leafy vegetables

INTRODUCTION

Green leafy vegetables also called dark green leafy vegetables, leafy greens, or greens are edible plant leaves. A person can eat some leafy greens as raw, while others may require cooking. As the name implies people can typically identify these vegetables by their green colour and edible leaves.

Vegetables make up a major portion of the diet of humans in many parts of the world and are considered essential for well-balanced diets in that green leafy vegetables play an important role in human nutrition. According to Indian Council of Medical Research (ICMR), recommended dietary allowance of vegetables is 300 g in which consumption of 50 g of leafy vegetables is mandatory. Green leafy vegetables are made up of cellulose, hemi cellulose and pectin substances which give them their texture and firmness. Leafy greens are healthy source of carbohydrates, typically contain less fat and calories than many other foods but also contain adequate amount of protein, dietary fibers, minerals, vitamins and other nutrients.

Green leafy vegetables often contain bio active compounds such as niacin, omega-3-fatty acids, flavonoids, carotenoids, sulforaphane and others (Aslam *et al*., 2020). These compounds can provide antioxidant and anti-inflammatory properties which may lead to a vast array of health benefits such as reduced risk for health conditions like stroke, anemia, high blood pressure, certain cancers and diabetes. They may also help to improve immunity, health of gut, heart, bone and skin. They are very important protective foods that are useful for the maintenance of health and prevention of various diseases. A study found that daily serving of leafy greens may help to slow the cognitive decline that can come with aging (Morris *et al*., 2017). They are valuable source of nutrients especially in rural areas where they contribute substantially to minerals, vitamins, fibers, proteins and other nutrients which are usually in short supply in daily diets.

Post-harvest losses of leafy vegetables is one of the important production problems estimated over 30 per cent which is generally caused by poor handling and storage conditions. Post-harvest losses is about 25 per cent which is mainly due its high perish ability due to high respiration rate and rapid deterioration after harvest, poor handling after harvesting, improper packaging and lack of improved storage techniques *etc.* Ascorbic acid, citric acid and benzoic acids are the most widely used post-harvest chemicals to enhance the storage life and delaying the colour change of harvested produce by inhibiting oxidation of cut leafy vegetables and improvement of shelf life in leafy vegetables, respectively. Natural preservatives like common salt and sugar are also potential and cheap sources to increase the post-harvest shelf life and quality standards through exosmosis of water which inhibit the growth of microorganisms and endogenous sugar levels increases shelf life. Rapid loss of water from leafy vegetables is a serious problem and packing with suitable material is advocated. Appropriate packaging helps to maintain high humidity, inhibit wilting and reduce weight loss (Brandl and Mandrell, 2002) . Therefore, selection of suitable packing material is an important issue apart from its easy availability. Leafy vegetables contain high respiration rate and knowledge on respiration rate and ethylene production will help to understand post-harvest behaviour of leafy vegetables under different chemical treatments and packing condition, thereby providing information for the selection of appropriate chemical treatment and packaging for the leafy vegetable.

Table 1: Difference between palak and spinach

PALAK	SPINACH
◆ SN : *Beta vulgaris* var. *bengalensis* Hort. ◆ 2n = 18 ◆ Origin : Indochinese region ◆ Leaves with margin ◆ Produces hermaphrodite flower ◆ Tolerates high temperature and grows well in hot weather	◆ SN : *Spinacia oleracea* L. ◆ 2n = 12 ◆ Origin : Persia ◆ Leaves with lobed leaf margin ◆ Produces staminate, pistillate and hermaphrodite flower ◆ Purely a cool season crop and cannot tolerate high temperature

Table 2: Nutritional composition of palak and spinach

Components	Palak	Spinach
Energy (k Cal)	46.00	23.00
Moisture (%)	86.40	93.20
Protein (g)	3.40	2.86
Fat (g)	0.80	0.39
Carbohydrate (g)	6.50	3.63
Thiamine (mg)	0.26	0.08
Riboflavin (mg)	0.56	0.19
Niacin (mg)	3.30	0.72
Ascorbic acid (mg)	70.00	28.10
Ca (mg)	380.00	99.00
Fiber (g)	3.68	2.20

Source*: palak - ecoursesonline.iasri.res.in

spinach - USDA

Figure 1.
Scientific name : *Beta vulgaris* var. *bengalensis* Hort.
Vernacular name : Palak, Indian spinach, Spinach beet

Figure 2.
Scientific name : *Spinacia oleracea* L.
Vernacular name : Vilayati palak

Figure 3.
Scientific name : *Basella alba* L.
Vernacular name : Malbar spinach, Basale, Indian spinach

RECENT ADVANCES IN PALAK

CROP IMPROVEMRNT

Table 3: Development of varieties

Variety	Parentage	Features
All Green (IARI)	Selection from a local type	Leaves green, entire margin and seed stalks in 75 days i n winter. Suitable for September sowing.
Pusa Palak (IARI)	Hybridization Swiss chard × Local Palak	Leaves uniform green with red pigmentation and late bolting.
Pusa Jyoti (IARI)	Selection from colchicine induced polyploid (All green)	Leaves thick, dark green, puckered and giant size. Wavy margin and late bolting. Suitable for sowing in September. Rich in vitamins and minerals.
Pusa Harit (IARI)	Hybridization Sugar beet × Local Palak	Plants erect, leaves upright, thick, dark green, slightly wavy margins with short petiole. Quick rejuvenation of cuttings, very late bolting and wide adaptability.
Pusa Bharati (IARI)	Selection	Leaves are smooth and green without red pigmentation, suitable for rainy and summer seasons. Rich in vitamin B and C.
H.S. 23 (HAU, Hissar)	Selection from a local type	Leaves are light green, medium-sized and quick growing in nature.
Arka Anupama (IIHR)	IIHR-10 × IIHR-8 followed by pedigree selection up to F_7 generation	Resistant against cercospora leaf spot, excellent c ooking quality and rich in vitamins and minerals.
Pant composite (GBPAUT)	Composite variety	High yielding and tolerant to cercospora leaf spot.
Jobner Green (RAU, Jobner)	Spontaneous mutation fro m Selection 5-local type	Leaves uniform, green, large, thick, entire margin, strong flavour and taste and tolerant to high pH (up to 10.50).

Punjab green (PAU, Ludhiana)	Selection from a local type	Plants are semi-erect, leaves are glossy, thick, long and broad. Sweet in taste, succulent stem with mild purple pigmentation and low oxalic acid.
Palak Number 51-16 (MH)	Selection from a local type	Leaves are green, several cuttings and late bolting.
HS-23 (HAU)	Selection	6-8 cuttings in 15 days intervals.
Kashi Poi 1 (IARI)	-	Procumbent growth habit, high yielder and a good source of antioxidant.
Kashi Poi 2 and Kashi Poi 3 (IARI)	-	Quick growing and long durated crop up to 130 days

Hazra *et al.*, 2011

Private varieties

Sungro seeds (Haryana) : Sungro All Green

Annapurna Beej (Junagadh) : Red Kanka, White Kosla and Light Red Kosla

Tokita Seeds (Bengaluru) : Upright

Hazra *et al.*, 2011

Variety	Features
Sungro All Green	It has uniform green, smooth, tender leaves. 5-6 cuttings at 15 to 20 days interval. Late bolting type.
Upright	It has shiny dark green leaves, 18-20 leaves per plant, resistant to downey mildew and also rich in minerals.
White Kosla and Light Red Kosla	Can be grown in rainy and winter season. Both types are preferred by different locality and grown as a common leafy vegetable in states like Orissa, Bengal, Bihar, Jharkhand and Parts of Chattisgarh.
Red Kanka	It is red blood colour, grow very fast, soft and succulent leaves, generally cultivated in winter season. It is ready for harvest in 25 days after seed sowing. One time harvest is commonly practiced.

Indian Institute of Vegetable Research

Twelve genotypes/variety of beet leaf (palak) were evaluated for morphological traits and seeds were multiplied for further evaluation. In October sowing, the biomass yield potential of most promising three genotypes *i.e.* VRPLK-2, VRPLK-7 and VRPLK-14 ranged from 650-700 q per ha. Further they evaluated these three genotypes and selected 'VRPLK-2' as promising genotype and compared it with popular variety *i.e.* All Green by sowing in four seasons. The respective biomass yield of VRPLK-2 and All Green was 885.00 and

646.00 q per ha in mid-September, 709.00 and 503.00 q per ha in mid-October, 515.00 and 355.00 q per ha in mid-November, 171.00 and 112.00 q per ha in mid-December, 151.00 and 58.00 q per ha in mid-January, 121.00 and 49.00 q per ha in mid-February, 234.00 and 119.00 q per ha in mid-March, 188.00 and 110.00 q per ha in mid-April, 181.00 and 109.00 q per ha in mid- May, 195.00 and 113.00 q per ha in mid-June, 202.00 and 121.00 q per ha in mid-July and 490.00 and 305.00 q per ha in mid-August, which is correspondingly 36.90, 40.90, 45.00, 52.70, 159.40, 148.90, 96.10, 70.70, 66.20, 72.60, 72.60, 66.90 and 62.20 per cent higher than check variety All Green. Further, VRPLK-2 showed delayed bolting habit *i.e*. 22-30 days late as compared to other varieties/genotypes.

CROP PRODUCTION

USE OF BIOSTIMULATANTS

Brassinolide was isolated from the pollen of rape, brassinolide typically showed a synergistic relationship with IAA. It has function of short elongation promotions of growth and development, promotion of ethylene biosynthesis and epinasty. Triacontanol was first identified by Chiebnall *et al*. (1933) as a natural component of plants *Medicago sativa*, a thirty carbon primary alcohol compound. It has a major effect on photosynthesis stimulation and enhanced water uptake which eventually results in an increased dry weight and it also hastens the cell elongation and division and results in the increased fruit size due to assimilation of more carbohydrates. Utilities of brassinolide and triacontanol in vegetable are opening new aspects of research on vegetable crops. Use of these two growth regulators on leafy vegetables particularly in palak is very scarce till date. Use of triacontanol at 1.5 ppm showed better results in flowering, yield, lea f yield and seed yield attributes (Thapa *et a*l., 2010).

BIO FORTIFICATION

Iron is one of the important nutrients required by human body and deficiency of iron causes anemia. Its major source of intake is by vegetables that too by leafy vegetables. So fortification was also tried palak leaves (*Beta vulgaris* var. *bengalensis*) as it is one of most consumed leafy vegetables in India. Application of iron fertilizer *i.e*. ferrous sulphate heptahydrate ($FeSO_4$ $7H_2O$, 16% Fe) at 100 per cent of recommended dose (0.5 g/lit of water) through foliar spray at four weeks after sowing not only fortifies iron upto 19.35 mg but also fortifies ascorbic acid, vit A and chlorophyll up to 78.33 mg, 8403.57 IU and 630.20 mg respectively (Chatterjee *et al*., 2020).

SOILLESS CULTIVATION

Soil-less cultivation is a new advanced method for improving cultivation of different vegetable crops. It is a method of growing vegetables without the using soil as a rooting medium, in which the inorganic nutrients absorbed by the roots are supplied through irrigation water. Growing palak in hydroponics with 5 % jeevamrit spray is beneficial and is economical (Rahul, 2020).

Aquaponics farming is a resilient farming system that offers wellness and better nutrition. It is a sustainable method of growing both fish and vegetables. It is becoming quite popular with individuals, entrepreneurs, educators, missions, and governments interested in modern farming. Hussain *et al*., (2015) experimented with constant flow rates in the aquaponic system with *Cyprinus carpio* var. *koi* and *Beta vulgaris* var. *bengalensis* for a period of 45 days and concluded that growing palak and fish in aquaponics with constant flow rate of 1.5 l per min is beneficial for both fish and palak growth.

For cultivation of vegetables in soil less media IIHR has released two nutrient solutions named Arka sasya poshak ras (21/11/2020) and Arka nutri grow (19/06/2020). The liquid nutrient formulation (comprising solutions A and B) is a unique balanced blend of the macro (N, P, K, Ca, Mg and S) and micro nutrients (Fe, Mn, Cu, Zn, B and Mo) which are required to support the growth of vegetables grown on cocopeat. This nutrient formulation is suitable for most commonly grown vegetables (tomato, chilli, cabbage, zucchini, cucumber, ridge gourd, French bean, peas, cow pea and dolichos etc.) and leafy vegetables (amaranthus, coriander and palak etc.)

Figure 5. Arka sasya poshak ras and Arka nutri grow

NANO TECHNOLOGY

To meet demand of food supply over increasing population, recently nanotechnology has occupied a prominent position in transforming agricultural sector and environment sustainability. The expansion of nano devices (<100 nm size) could be used for wide range of extensive applications for increasing seed germination, seedling growth, plant morho-physiological development and alleviation of stress environments. The unusual idiomatic properties of nanoparticles with high surface to volume ratio, better catalytic surface, high reactivity capacity, rapid chemical reaction and adsorb abundant water may result in different environmental behaviors than the bulk materials. The metal based nanoparticles (ZnO, TiO_2, Fe_2O_3, CuO) were capable to penetrate into the plant cell causing damage by interacting with sulphur and phosphorus containing compounds such as DNA and protein (Amarendra and Krishna, 2010) and also optimizing plant metabolic processes at the early growth stages (Taran *et al*., 2014). The interaction between nanoparticles and plant cell resulted in changes of gene expression and connected biological pathways which finally changed the plant characteristics. The positive impact of nanoparticles were documented in array of crop plants (Monica and Cremonini, 2009) and their response depending on type of nanoparticles used, concentration and species. In palak TiO_2 nano particles can be used for improvement of morphological characters and ZnO at 25 ppm for yield attributes (Das *et al*., 2022).

ORGANIC CULTIVATION

Organic farming, also known as ecological farming or biological farming, is an agricultural system that uses fertilizers of organic origin such as compost manure, green manure, and bone meal and places emphasis on techniques such as crop rotation and companion planting

Three years study in Nagaland on organic production of spinach beet revealed that application of vermicompost five tonnes/ha + PSB + *Azospirillum* (each 5 kg/ha) registered maximum leaf yield (172.83 q/ha) which was at par to application of FYM 20 tonnes/ha + PSB + *Azospirillum* (each 5 kg/ha). However, maximum net returns (2,04,595 Rs./ha) and B:C ratio (1:4.35) was recorded with application of FYM 20 tonnes/ha + PSB + *Azospirillum* (each 5 kg/ha). Hence, application of FYM 20 tonnes/ha + PSB + *Azospirillum* (each 5 kg/ha) was recommended for organic production of spinach beet (palak) in Agro-climatic zone III, by IARI .

INTEGRATED NUTRIENT MANAGEMENT

Integrated Nutrient Management (INM) refers to maintenance of soil fertility and plant nutrient supply to an optimum level for sustaining the desired crop productivity through optimisation of the benefits from all possible sources of plant nutrients in an integrated manner. Navaneetha *et al.,* 2022 conducted an experiment on effect of integrated nutrient management of spinach on quality attributes under shade net condition at Dharwad. The quality parameters like oxalate, iron and carotenoid content were found best in 50 per cent RDF + 50 per cent RDN through FYM, vermicompost and neem cake (2:2:1) + *Azotobacter* and PSB with values of 328.65 mg per 100 g, 7.23 mg per 100 g and 3.98 mg per 100 g, respectively. While, calcium (365.30 mg per 100 g) and magnesium content (91.44 mg per100 g) was found highest with 100 per cent RDN through FYM, vermicompost and neem cake (2:2:1) + *Azotobacter* and PSB.

IMPROVEMENT OF SHELF LIFE

Post-harvest losses of leafy vegetables is one of the important production problems estimated over 30 per cent which is generally caused by poor handling and storage conditions. Post-harvest losses in spinach beet is about 25 per cent which is mainly due its high perish ability due to high respiration rate and rapid deterioration after harvest, poor handling after harvesting, improper packaging and lack of improved storage techniques etc. Treating of palak with 0.3 per cent ascorbic acid and followed by LDPE packaging is good for shelf life (5days), retention ascorbic acid (26.80 mg) and minimum ethylene production (8.41 ml/g/hr) (Prasad *et al*., 2018).

To address the problem of shelf life Indian Institute of Horticultural Research, Bengaluru also come up with Arka high humidity storage box designed and developed by ICAR-IIHR maintains higher relative humidity needed by green leafy vegetables to retain freshness. Green leafy vegetables such as amaranthus, palak, fenugreek, mint and coriander stored in Arka high humidity storage box had higher freshness, lesser physiological loss in weight (PLW %) and lesser spoilage. Green leafy vegetables had a shelf life of 48 hours in Arka high humidity storage box kept in room temperature (26-28°C, 52 % RH) as compared to shelf life of less than 24 hours in commercial practice of covering green leafy vegetable with wet gunny cloth. With no electricity consumption and without any refrigeration, freshness of green leafy vegetables is retained in Arka high humidity storage box. It is highly suitable for vegetable retail shops, super markets and vegetable vendors. This Arka high humidity storage box gives hygienic way of storage of fresh green leafy vegetables.

Figure 6. Arka high humidity storage box

OTHER USES

Inter cropping of leafy vegetables with *Ailanthus excelsa* tree of three years old was tried by Rajalingam *et a*l., 2017 at Tamil Nadu. They observed that, the growth and yield of intercrops were reduced in association with *Ailanthus* when compared to sole cropping. Among the test crops, palak was most affected and Chinese

spinach was least affected. The benefit cost ratio from the crop was highest with Chinese spinach (3.45) and the lowest with tropical amaranth (1.77) under intercropping. But, growth of *Ailanthus* was influenced due to intercropping with palak. The tree height and DBH of *Ailanthus* were observed highest when intercropped with palak 19.51 per cent and 20.50 per cent increase, respectively over tree alone.

Curing is an old method of meat preservation strategy that consists of the use of marine salt containing nitrate on the surface of meat cuts and pieces. Currently it is known that curing occurs mainly from the action of nitrate (NO_3) and nitrite (NO_2) which improve colour stability, slow oxidative reactions and impart the characteristic cured flavour to meat products. The process is centered in the stabilization of the iron atom in the porphyrin ring of myoglobin. Nitric oxide (obtained from nitrite) interacts with the iron atom of myoglobin and generates nitrosocompounds, which increases the structural stability of this muscle pigment by preventing the loss of iron. Once the iron atom of myoglobin is preserved in the structure of myoglobin, the oxidative stability of the meat product improves and the progression of oxidative reactions catalyzed is limited. Consequently, the degradation of lipids and proteins as well as sensory decay during storage are delayed. Nitrite also improves the safety of meat products by inhibiting the growth of spoilage and pathogenic micro-organisms. There are two method of curing, one is by treating nitrate extracts from *Beta vulgaris* group with micro-organisms with nitrate reductase activity, this solution is used to cure the meat. Second method is by adding extracts of *Beta vulgaris* group and starter culture directly to meat for curing effect.

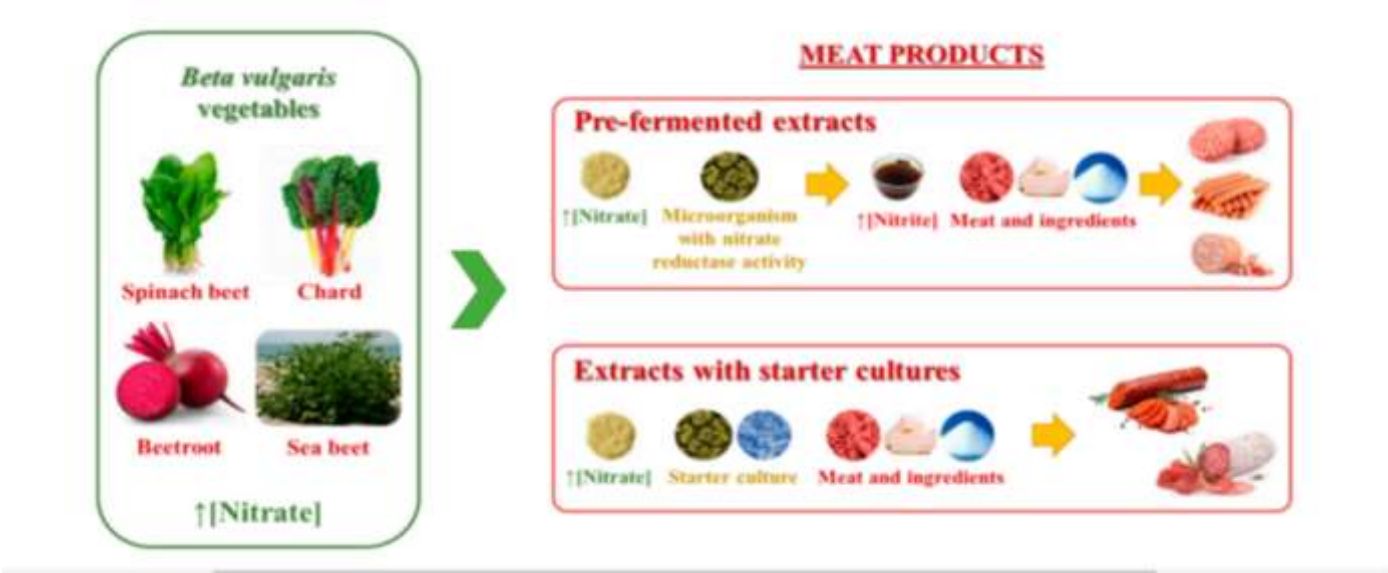

Figure 7. Schematic representation of the main strategic uses of *Beta vulgaris* extracts in the production of cured meat

Second method is used in palak by Paulo *et al.*, 2021. Three gram per kg mixed extract of beetroot with celery or palak powder used for fermented pork sausage, *Staphylococcus carnosus, Staphylococcus xylosus* and *Lactobacillus sakei* as starter culture and observed, no effect on pH, lactic acid bacteria, water activity and sensory attributes.

Table 4: Types of spinach

Hazra *et al.*, 2011

Type	Variety	Features
Savoy spinach	Blooms dale and Regiment	Wavy leaf, dull green in colour and marginally harsh fl avor
Semi-Savoy spinach	Tyee and Catalina	Semi -creased leaves and utilized in cooking
Flat leaved sp inach	Space spinach and Red carniva l	Smooth and level leaves, delicate surface and ma rginally sweet flavour

BIOSTIMULANTS

The pressing issue of global food security coupled with the projections for global population increase and climate change pose major challenges for the horticultural industry and researchers with respect to sustainability, dictating maximization of the production per unit area while minimizing the environmental impact of vegetable cropping systems. One of the most promising tools to tackle these rising concerns appears to be the use of plant Biostimulants (PBs) which include natural substances (humic acids, protein hydrolysates and sea weed extracts) and beneficial microorganisms (mycorrhizal fungi and plant growth promoting rhizobacteria of strains belonging to the genera *Azospirillum*, *Azotobacter* and *Rhizobium* spp.). As defined by the European Biostimulant Industry Council (EBIC), PBs are 'substances and/or microorganisms applied to plants with the intention to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits regardless of its nutrients content. According to Battacharyya *et al*., (2019) protein hydrolysates (PHs) along with macro-algae sea weed extracts (SWE) represent two important categories of natural substances PBs. The main components of commercial PHs are a mixture of free amino acids, oligo- and polypeptides sourced from animal or plant origins; whereas commercial SWE, in particular the brown macro-algae (*Ascophyllum nodosum* and *Ecklonia maxima*) are important sources of polysaccharides (alginates, fucoidans, laminarans and mannitol), phenolic compounds as well as phytohormones (auxins, cytokinins, gibberellins and brassinosteroids). Use of vegetable oils, herbal extracts and *Ascophyllum nodosum* based extract can maximize dry matter content, dry weight, protein content, calcium. Legume-derived protein hydrolysate produced maximum yield and potassium content (Rouphael *et al*., 2018).

LAC WASTE

Indian Agricultural Research Institute (IARI) came up with an unique idea of using lac waste and was successful in the attempt. Lac mud is the waste product of lac processing industries which is about 2.5-4.5per cent on dry and wet weight basis, respectively of the raw material (stick lac) processed. In absence of a proper disposal method of lac mud, it causes pollution. Enriched lac mud application ensures quality vegetable production, saving of inorganic fertilizers, improvement in soil fertility status and moreover it may give another diversified dimension to lac industry, which may be helpful to sustain the lac production system. Application of decomposed enriched lac mud in vegetables produced 22.00, 22.50 and 18.30 per cent higher yield of brinjal,

tomato and spinach, respectively over 100 per cent nitrogen through inorganic source (farmers practice). This technology saves 48 per cent of N and P fertilizers, and 65 per cent of K fertilizer in brinjal and tomato. In spinach, similar saving in N and P fertilizers along with 36.60 per cent saving of K fertilizers was recorded.

WASHING STATERGIES

After green revolution use of chemicals in production of crops has increased, despite their toxicity, pesticides are widely used to protect crops against insects, weeds, fungi and other pests. Accordingly, pesticides are indispensable for food productivity and quality. The application of pesticides may result in residues on vegetables and these specified derivatives can induce adverse health effects (acute and chronic effects such as reproductive harm, carcinogenicity, neurological toxicity and cell dysplasia). Therefore, excessive consumption of residual pesticides through raw or processed vegetables is dangerous for consumers and thus warrants an effective removal strategy.

Many studies have used methods, such as peeling/trimming, washing/rinsing, soaking and blanching/boiling mainly for fruits and fruiting vegetables. However, as these fruits can be peeled and washed, it is comparatively simple and easy to remove pesticide residues on these fruits compared to those on vegetables, especially leafy vegetables. It is difficult to apply these methods to leafy vegetables, as they cannot be peeled or trimmed. Therefore, the removal method of various pesticides from vegetables must be investigated. As leafy vegetables cannot be peeled, they are relatively difficult to clean; only attached dust, insects and foreign substances can be removed. In addition, owing to the large surface area of these vegetables, pesticide residues are likely to remain on their surfaces leafy vegetables are used in various cuisines worldwide. Hence, an efficient method is required to remove pesticide residues from leafy vegetables in households. Among all methods, washing (tap water) is known as the most common and efficient method of pesticide residue removal in general households. However, as many pesticides are hydrophobic, washing with tap water is inefficient for pesticide residue removal. Cooking is known to be effective at removing some volatile pesticides but is ineffective at removing less volatile pesticides. Therefore, depending on the characteristics of pesticides, various removal methods should be used.

Spinach's economic part is leaf and as it is a short durated crop, it shows retention effect which is very harmful to human beings. To address this problem,Yang *et al*., 2022 conducted an experiment to select better washing strategy to reduce retention effect in spinach and concluded that washing with running water is better to over come this problem as it reduced up to 87.80 per cent.

OTHER USES

Due to industrial revolution there is an huge increment in number of industries in country and also in the world. The waste from these mainly contains toxic substance and heavy metals which is released to water bodies causes toxicity to land and plants grown in that area. Heavy metals are a group of metal or metalloids that are toxic to animals and human beings even at lower concentrations. They tend to accumulate in a living organism *i.e*., plants and animals, so their uptake is ultimately a severe threat to human health. Heavy metal contaminated soil adversely affect the growth and development of plant and microorganisms which results in a

reduction of crop productivity. Among various heavy metals, lead (Pb) has become a significant soil contaminant. Although Pb is a nonessential element, it gets absorbed by the crop plants and inhibits plant growth.

Spinach is a very good accumulator of metals, especially Pb (Rizwan *et al*., 2013). To examine the combined effects of ACC deaminase producing rhizobacteria and compost mixed biochar (CB) regarding immobilization of Pb in spinach cultivated in artificially induced Pb-contaminated soil. Use of CB + PGPR (*Bacillus amyloliquefaciens*) shows promising results with respect to organic content in soil, root weight and lower lead toxicity in roots.

The study was carried out by Samah M El-Sayed (2020) exclusively to characterize and evaluate the activity of spinach leaves nano-powder and use it as a functional material for the preparation of a beneficial healthy ultra filtered soft cheese (UF-soft cheese). They use spinach nano powder in manufacture of ultra purified cheese in National Research Centre, Giza, Egypt. A study on use of spinach powder as functional ingredient in the manufacture of UF-Soft cheese. They used nano powder of spinach in four concentration (0.50 ppm, 1.00 ppm, 1.50 ppm and 2.00 ppm). The quality of the cheeses was assessed by measuring their chemical compositions, colors, sensory and antioxidant properties. They observed that the total solid, protein and acidity contents increased significantly with the increased percentage of added spinach nano-powder reaching maximum values after four weeks of cold storage. Cheese containing 0.5 and 1 ppm spinach powder demonstrated higher values for sensory parameters than other treatments.

Indian Agriculture Research Institute has prepared a snack using spinach and other components like maize, defatted soy flour, sesame seeds and spinach powder. The best combination had 74 per cent maize, 15 per cent defatted soy flour, 5 per cent sesame seeds and 6 per cent spinach powder. The product obtained had 18.2 per cent protein and 3.01 per cent total minerals. The antioxidant activity was observed to be 24.61 per cent, flavonoids 7.66 mg per 100g and overall sensory score as 8.11. The expansion ratio, water absorption, water solubility index and whiteness index were observed to be 3.36, 5.41g per g, 28.08 per cent and 54.89 respectively.

Figure 8 . Protein snack food made from spinach

PROSPECTS

- As they have good antioxidant property, developments are necessary in fortifying antioxidant compounds.
- Discovering of compounds responsible for anti-inflammatory property and methods to isolate them.
- There is a tremendous scope for development of varieties for higher yield and nutritional quality.
- Hydroponics and aquaponics method of production and practices are to be standardized.
- Education and demonstration of growing palak in kitchen and homestead garden are to be provided.
- Use of bioremediators to mitigate the heavy metal toxicity in palak and spinach.
- There is a necessity to increase the shelf life of palak and spinach as they are highly perishable in nature.
- Commercialization of minimal processing of palak and spinach can be done.
- There is a need for value addition in palak and spinach.

CONCLUSION

Palak and spinach contain all the nutrition, vitamins and minerals that are necessary in day to day life of human beings. Flexibility in growing condition, short durated nature and high net returns is needed to make them a complete vegetable crop from producer and consumer point of view.

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