



Trends in Using Nutrient Supplements in Silkworm (*Bombyx Mori* L.) Nutrition

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CONTEXT

The *Bombyx mori* L. silkworm is an economically important lepidopteran insect for silk production.

As a monophagous insect, silkworms require certain nutrients for their growth and production (i.e., carbohydrates, proteins, amino acids, sugars, fatty acids, vitamins and micronutrients) that are provided by the mulberry (*Morus* spp.) leaves.

The quality of mulberry leaves depends on environmental conditions and affects the cocoons production and silk quality.

The nutrition and health status of silkworm larvae are the main factors influencing silk production.

Over time, researchers searched alternatives to enrich the mulberry leaves with nutrient supplements such as amino acids (glycine, asparagine, arginine, serine), vitamins (vitamin B-complex, vitamin C) and minerals (calcium, phosphorus, zinc, magnesium, potassium, copper, selenium) to improve its quality and to increase the silkworm productivity and health.

OBJECTIVE

This review highlighted the recent trends in silkworm nutrition by using natural feed supplements. Effects of various probiotics such as *Lactobacillus* spp. (*L. acidophilus*, *L. plantarum*), *Staphylococcus* spp., yeast (*Saccharomyces cerevisiae*), and algae (*Spirulina*) as ways to fortify the mulberry leaves to modulate the larval and cocoon economic traits of silkworm were discussed.

PROBIOTICS - "live microorganisms that when administered in adequate amounts confer a significant health benefit on the host" (FAO-WHO).

EFFECTS OF MULLBERRY LEAVES PROBIOTICS SUPPLEMENTATION IN SILKWORM *B. mori*

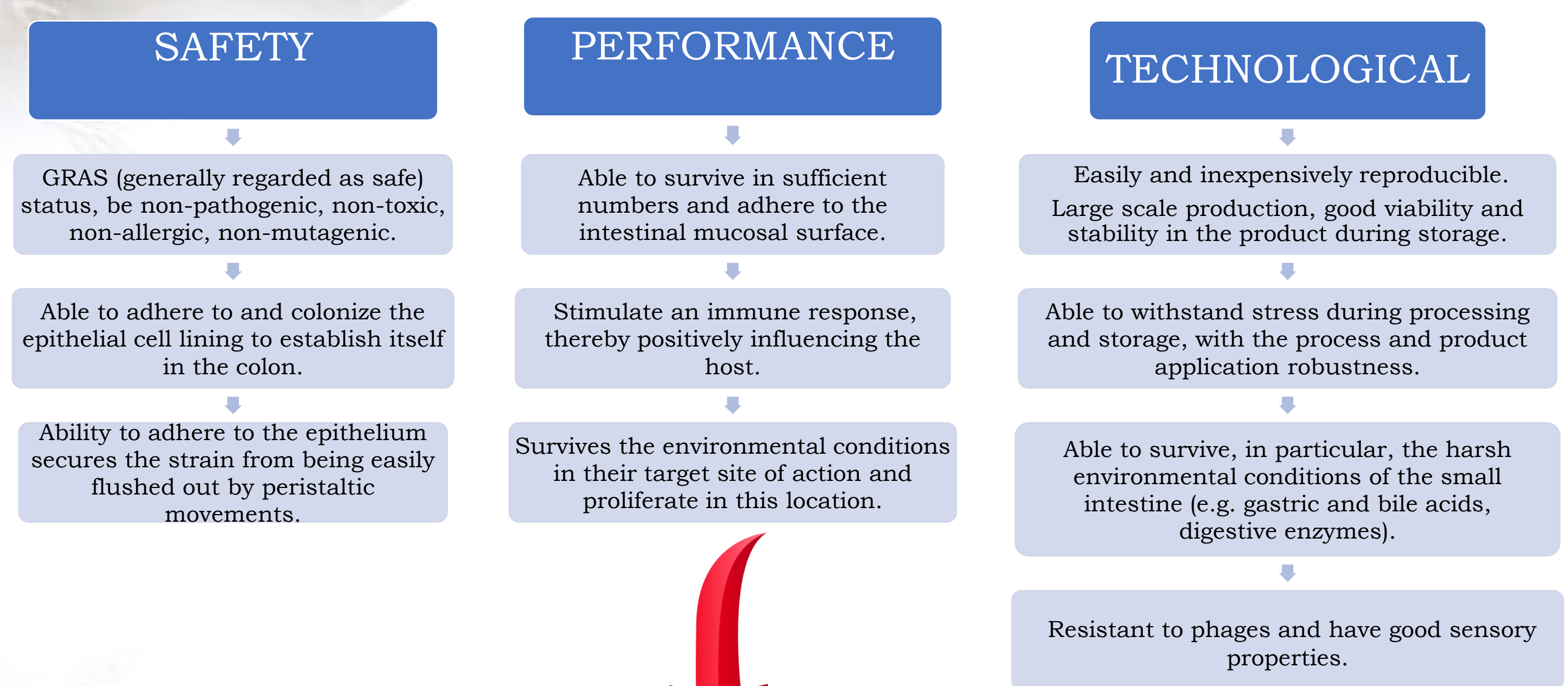
Reference	Probiotic	Doses/ Concentration	Instars	Main results
Singh et al. (2005)	<i>Lactobacillus plantarum</i>	ns	ns	Improved larval body weight, cocoon weight, shell weight and pupation percentage of silkworm larvae when fed on mulberry leaves.
Masthan et al. (2011)	<i>Saccharomyces cerevisiae</i>	100, 200, 300 ppm	ns	300 ppm yeast increase the cocoon characters; single cocoon weight, single shell weight, pupal weight and silk filament length when compared with control. Significant differences were found between 300 ppm and other two concentrations. Between 100 and 200 ppm concentrations are not significant differences except for filament length.
Esaivani et al. (2014)	<i>Saccharomyces cerevisiae</i>	1, 3, 5%	ns	Increase amylase and invertase activity in the digestive juice. Improved immunity and quality silk production. 3 and 5% <i>S. cerevisiae</i> increased shell ratio, filament length and denier percentages.
Suraporn et al. (2015)	<i>Lactobacillus acidophilus</i>	108 cfu/ml	3 to 5 th larval instars	Improved quality parameters: survival ratio, mature larval weight, pupation ratio, cocoon weight and cocoon shell ratio. Stimulated growth factors leading to an increase in the silk yield and to an improvement of the silk harvest.
Taha et al. (2017)	<i>Saccharomyces cerevisiae</i> and <i>Bifidobacterium bifidum</i>	109 cfu/ml	5 th larval instar	Both probiotics increase effective rate of rearing (ERR), larval weight, cocooning and pupation percentages. Increase digestive enzyme activities (protease, amylase and invertase) in probiotic treated silkworms than control.
Masthan et al. (2017)	<i>Spirulina</i> , <i>Saccharomyces cerevisiae</i> , <i>Lactobacillus acidophilus</i> and <i>Lactobacillus sporogens</i>	300 ppm of each	ns	<i>Spirulina</i> and <i>S. cerevisiae</i> yielded better fibroin content indicating the good quality silk when compared to <i>L. acidophilus</i> and <i>L. sporogens</i> .
Shruti et al. (2019)	<i>Spirulina</i> , <i>Azolla</i> , yeast and soy milk	1, 2, 3, 4 and 5%	4 th larval instar	<i>Azolla</i> was found to be superior for an effective rate of rearing. Cocoon weight on the day of 50 per cent spinning followed by soy milk and yeast in comparison with control (unsupplementation) in both the rearings.
Saranya et al. (2019)	<i>Staphylococcus gallinarum</i> strain SWGB 7 and <i>Staphylococcus arlettae</i> strain SWGB 16	108 cfu/ml	4 th larval instar	Probiotic increase larval growth and cocoon characters than the control with enhanced immunity and quality silk production. Probiotic strains SWGB 7 <i>Staphylococcus gallinarum</i> and SWGB 16 <i>Staphylococcus arlettae</i> could serve as a potential probiotic candidate for silkworm growth and development.
Hassan (2020)	Soy flour and <i>Spirulina</i>	2.5, 5 and 10% w/v	5 th larval instar	Soy flour and <i>Spirulina</i> fortified mulberry leaves had beneficial effects on the larval growth, and exhibited good quality and quantity of the cocoon yield and silk production owing to the improvement in protein synthesis and protease enzyme activity. Supplementations with 5% soy flour archives better palatability to silkworm larvae, while <i>Spirulina</i> can be used with the lesser concentration (2.5%) to increase the silk yield.

CONCLUSIONS

Mulberry leaves quality is one of the major factors which influences silkworm development, it is, therefore, essential to improve either food quality or appetite (or both) of larval instars of silkworms.

The enrichment of mulberry leaves with probiotics represents an eco-friendly strategy to improve the growth performance, cocoon productivity and silk quality.

SPECIFIC PROPERTIES OF PROBIOTIC STRAINS



PROBIOTIC MODE OF ACTIONS

- ✓ Enhancement of the epithelial barrier.
- ✓ Increased adhesion to intestinal mucosa and inhibition of pathogen adhesion.
- ✓ Competitive exclusion of pathogenic microorganisms.
- ✓ Production of antimicrobial substances.
- ✓ Modulation of the immune system.
- ✓ Immune effects.

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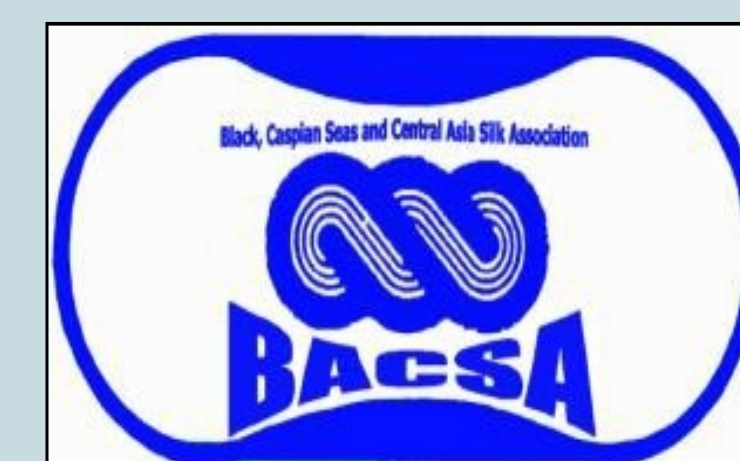
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10th BACSA INTERNATIONAL CONFERENCE
"Regeneration of Sericultural Industries in 21st Century",
REGESERI - 2023, SOUFLI, GREECE



An Insight on Pharmacological Functions of Silkworm Pupae (*Bombyx mori* L.)



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CONTEXT

- The main concerns and challenges of raising silkworms include the economic value, mulberry management, and developing of highly productive breeds for genetic variety.
- Even though sericulture has seen a decline, a number of elements continue to significantly support its economic sustainability.
- Bombyx mori* L. is an ideal lepidopteran species representative of many scientific studies, a model of studies for medicine and a significant insect from an ecological standpoint.
- The economic potential of sericulture is determined by the ability to value its main output in various ways (medicine, model insects in genetic and physiology research, food for humans and in animals feeding, etc.).
- Throughout the technological flux of growing silkworm, at each phase are generated products (silk thread, pupae, excreta, eggs) with excellent application in various fields.



OBJECTIVE

Our objective consist on describe silkworm pupae's (SP) therapeutic value and functional characteristics

! The pupae are a highly nutrient-dense waste recommended as an edible by-product from the silkworm, which is left after reeling silk (Dong et al, 2017, Lamberti et al., 2019).

BIOACTIVE COMPOUNDS

- Attract interest their high-content in essential nutrients for health.
- Oiled and de-oiled SP have a protein level ranging from 51.6% to 70.6%, an excellent amino acids composition (mainly methionine), and a lipid content between 6.2 and 37.1% (DM bases) with an excellent fatty acids (FA) profile.
- SP contain a significant concentration of polyunsaturated FA (~44% of total FA), respectively omega-3 (α -linolenic acid, ~36-38%), omega-6 (linoleic acid, 6-8%), traces of DHA and EPA FAs., which lead to understanding of the crucial role that EFA play in maintaining overall health.
- Nutritionists claim that being rich in Ca and P, two nutrients crucial for children's growth, SP will be able to shield them from rickets and malnutrition.

APPLICATIONS

- Supplementing the human diet with SP oil may be an effective way to treat acute liver injury induced by an overdose of acetaminophen; to decrease the area of gastric ulcer and secretion. The oil content of SP ameliorates oxidative damage and reduces inflammations.
- SP may have neuroprotective effects by the stimulation of antioxidant enzymes and the cholinergic system.
- Due to the presence of polyphenolic groups and FA-like linoleic acid, SP may have antigenotoxic properties.
- Around 4% of the DM in SP skin is chitin, which can be converted into useful compounds. Chitin and chitosan derivatives are used in wound dressing, controlled release of drugs, and contact lenses.

Numerous biological actions of SP oil have been linked to improved blood circulation. By enriching SP oil with sodium salt solution through an esterification and saponification process, was demonstrated a beneficial effect as a meal and medication.

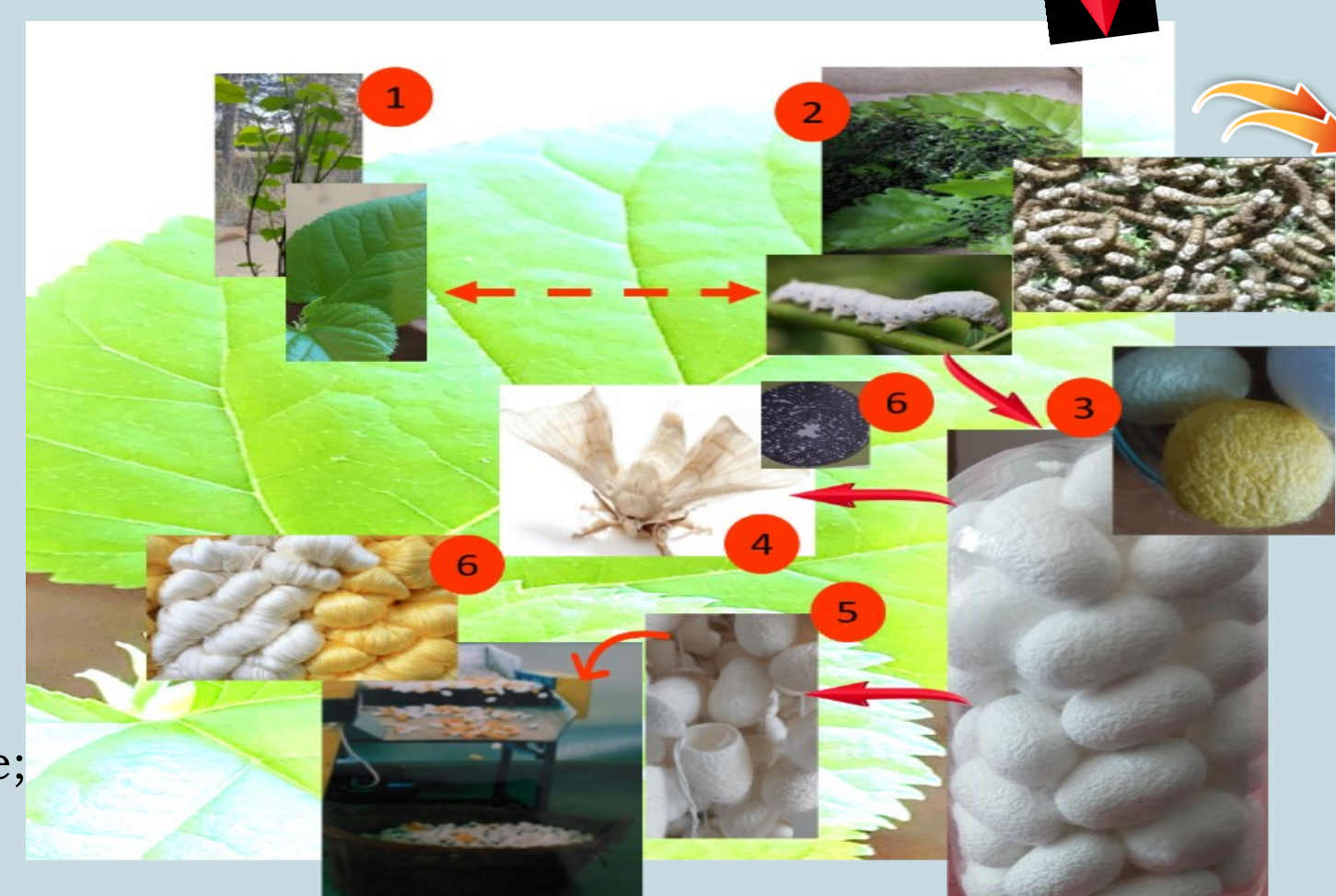
By transferring $\Delta 5$ and $\Delta 6$ desaturases to silkworm by mulberry leaves could make silkworm a new source of FAs, acting efficient for replacement of fish oils in animal diets.

It was explored and demonstrated the immunomodulatory, antibacterial, anticancer, antioxidant, hepatoprotective, antifatigue, and anti-apoptotic actions were among the numerous and complex medicinal impacts.

The SP compounds decrease plasma triglycerides, prevent fatty livers, prevent arteriosclerosis and thrombosis, increase cell vitality, strengthen the body's defenses system, and can act as wound dressing material.

As a precaution, it should be highlighted that the SP of *B. mori* can produce certain anti-nutrients such as phytate, phytic phosphorus, as well as tannic acid, alkaloid, flavonoids, saponin, and oxalate. These anti-nutrients are present but at low concentrations acceptable to humans.

Value chain of sericulture: 1. mulberry, leaves; 2. larvae; 3. pupae; 4. moth; 5. Silk thread; 6. eggs



CONCLUSIONS

We conclude that SP allows valorizing its active compounds for health.

The varied and intricate medicinal benefits, such as immunomodulatory, antibacterial, anticancer, antioxidant, hepatoprotective, antifatigue, and antiapoptotic actions, are remarkable.

Silkworm pupae bioactive compounds act by reducing plasma triglycerides, treating wounds and to control blood sugar levels, in preventing thrombosis and arteriosclerosis, as well in boosting cell vitality, and enhancing the body's defenses in metabolic disorders.

New medical ways of valorization can be researched: possible solutions for chemotherapy in the treatment of tumors, SP could be a source of anticancer drugs, act as natural antioxidants or for prevention and treatment of human cardiovascular disease.

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