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CHIA SEED IN HEALTH AND DISEASE PREVENTION: PRESENT USAGE AND FUTURE PERSPECTIVES

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Keywords:

Salvia hispanica L., Omega-3-alpha linolenic acid, CVS, Diabetes, Anticancer effects, Immune system, Obesity

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ABSTRACT: *Salvia hispanica* L. Well known as chia is gaining popularity day by day due to its nutritional value. This plant is native to Mexico, belonging to family Labiatae / Laminacea, and it was used as a superfood from ancient times. Chia is valued more due to its oil content as it consists of omega -3-alpha linolenic acid in higher amount along with various types of other nutrients, e.g., proteins, dietary fibers, antioxidants, *etc*. which is very beneficial to keep a person healthy and also it helps in prevention of many diseases like CVS, diabetes, obesity cancer and also it gives strength to our immune system. In the past few decades, we have noticed a certain growth in the market value of chia, and it is increasing day by day, not in a particular area or region but around the whole globe. In this paper, we have discussed all the important characteristics of chia (from its morphological characters to its pharmacological properties along with nutritional values and its today's marketing value) by collecting different kinds of literature and surveys.

INTRODUCTION: The exploitation of plants by human beings for the treatment of various diseases has been in practice for a very long time [1-6]. Herbal source of drugs constitutes a major part in all the traditional system of medicines. Chia (*Salvia hispanica* L.) is a well-known plant that belongs to the genus of Salvia, and it consists of approximately 900 different species of plants, shrubs, and brushes of Salvia Family [7]. The chia belongs to the Labiatae / Lamiaceae family containing the very high nutritional and therapeutic value. This species belongs to an annual plant growing mainly from western Mexico to northern Guatemala.

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S. hispanica is derived from the Spanish word "chian" which refers to oil-related substances, and it is also known as the powerhouse of omega-3 fatty acids containing other nutrition like proteins, dietary fibers, vitamins, minerals, and various polyphenolic antioxidants which is mainly used to avoid catabolism of chia seed [8]. Chia seeds are also known as functional foods or superfoods because of the fact that it consists of various and very high nutritional ingredients which protect and enhances the immune system. These days, the eye-catching fact about chia seed is the presence of high level linoleic and alpha-linolenic fatty acids because the main reason for the high content (approx. 60%) of oil is because of these omega-3 fatty acids. Therefore, the main purpose of this paper is to show the nutritional and therapeutic potential of chia seeds [9-10].

Background of Chia: After Carolus Linnaeus (1707-1778) *S. hispanica* got named who founded growing wild in the new world and disoriented with

a domestic plant from Spain (Edwards, 1819). Although, in Mexico chia is domestic and was introduced to Spain after Herna'n Corte's settled in Mexico. In Latin America, there is a special significance of chia (*S. hispanica* L.) seed since it has been consumed from ancient times by Mesoamerican people, and the population is attributed by the chia [10].

By historians, by Spaniard colonizers, and by natives, this is well documented that chianpinolli is a type of flour which was prepared through a common practice of roasting and grinding of seeds. Chianatoles were a common beverage that was prepared by adding Chinapinolli to tortillas, tamales, and several Aztec beverages. It was also offered to Aztec gods in their religious ceremonies, and they believed it as a food that provides power [11].

Chia was also banned by the Spanish kingdom due to its religious values, but it was survived in certain places in Mexico. Today, the cultivation of chia is done in many countries, especially in Latin America, but nowadays, Australia is becoming a larger producer of chia [12].

Morphology of Chia:

Plant: It is a type of annual plant. Flowers in these plants generally come in the summer season, and the colors of flowers are generally white or violet. The other morphology of this plant is summarised in **Table 1** [13-14].

FIG. 1: MIXED CHIA SEED

Seed: In spite of having a small size, it is very beneficial for the health, as it is a high source of omega -3 ALA with a high amount of fiber, iron content, and rich in antioxidants. The morphology of seed is mentioned in **Table 2** [15].

Apart from this, chia seed is a good source of vitamins and minerals like calcium, phosphorus, potassium, magnesium, iron, sodium, and zinc and also it contains niacin, vitamin A and C **Fig. 1**.

TABLE 1: MORPHOLOGICAL CHARACTERISTICS OF *S. HISPANICA* L. PLANT

Morphology	Description
Height	1m
Nature of leaf	Reverse petiolate
Size of leaf	4–8 cm long; 3–5 cm wide
Nature of flower	White or violet color, hermaphrodite
Size of flower	3-4 mm
Origin of flower	whorls on top of shoots
Nature of soil	Clay and sandy soils
Optimal weather	warm weather, high rainfall
Optimal temperatures	15-30°C
Fruits	schizocarps
Yield	500–600 kg seed/acre or 2500 kg/acre if proper agronomic conditions are maintained

TABLE 2: MORPHOLOGICAL CHARACTERISTICS OF *SALVIA HISPANICA* L. (CHIA SEED)

Morphology	Description
SIZE	Small, in mm in length
SHAPE	Oval
Humidity	40–50% for Argentinian seeds and around 1.6 for Mexican seeds
Storage condition	Very good as it is not hygroscopic in nature
Moisture content	5.80%
Protein	16.54%
Total lipids	30.74%
Total dietary fiber	34.40%
Total carbohydrates	42.21%

Insect Control: Chia leaves consist of various essential oils that have a potent repellent property, and they protect the plant from many insects. The name of these oils are β-caryophyllene, globulol, γ-muroleno, β-pinene, α-humoleno, germacren-B, and widdrol [16].

Chemical Constituents: It has been already reported that chia seeds content various active ingredients such as fatty acids and phenolic compounds, but there are many external factors which may become the valid reasons that cause variations in concentrations of these active compounds *e.g.*, cultivation area, climate changes nutrient content, and nature of the soil which may influence the conc. of active compounds [17-18]. In **Table 3,** the relation between the above-mentioned factors and the conc. of active compounds is summarised [19-20]. The main active constituent of

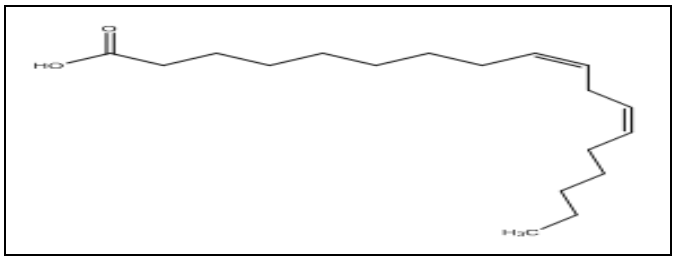
chia seed is omega3-alpha-linolenic acid which plays a vital role in the treatment of many diseases such as arthritis, cancer, heart-related disorders, *etc*. Apart from this, it is also used as an anti-inflammatory agent, anti-diabetic agent, lowering cholesterol level and also act as a cardio-protective and hepato-protective agent [20-21]. The other chemical constituents are omega-6 having thrombotic activities, myricetin, quercetin, kaempferol, and caffeic acid, which are basically flavanols and phenolic compounds [22-23] **Fig. 2**.

TABLE 3: FACTORS AFFECTING CONCENTRATION OF ACTIVE COMPOUNDS IN CHIA

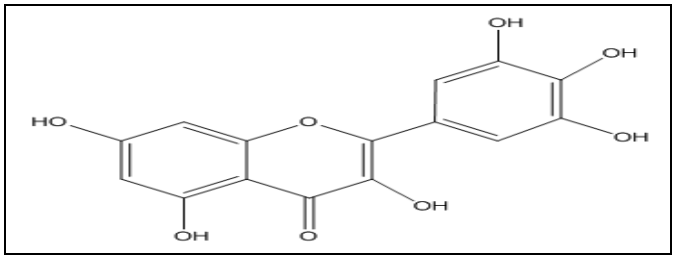
Factors	Concentration of active compounds
Temperature increases	Protein content reduced, polyunsaturated fatty acid content reduced
High altitude	Saturated fatty acid content reduced
Lower altitude	Saturated fatty acid content increases
Development stage – from early-stage to the matured stage	ALA reduced, LA and lignin content increases

Nutritional Value: Chia is a full packet of nutrients as it contains carbohydrates, lipids protein, fibers, vitamins, and minerals in specific concentrations, and due to its highly nutritive values, it has become a demanding food supplement [24].

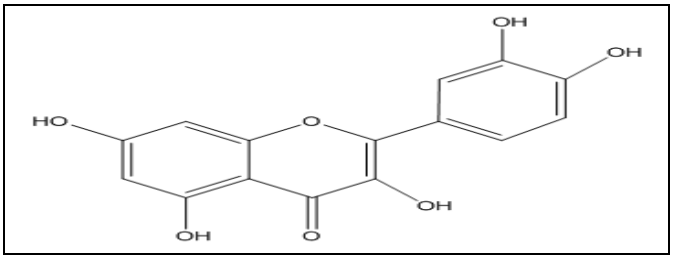
Protein Content: The amount is totally dependent on environmental as well as agricultural factors. In comparison with other grains amount of protein is much higher in chia seed as it contains 9 essentials amino acids [25]. It is also beneficial for those people who are suffering from coeliac disease as it is easy to digest because of the absence of gluten. Also, it helps in reducing body weight as it has already been mentioned in surveys and literature that regular consumption of protein can result in loss of fat; therefore, regular intake of chia seeds will help in reducing the obesity [26]. It has been already mentioned in the literature that protein content is inversely related to temperature. Globulin (approx. 52%) is the main protein present in chia. Albumins and globulins show good stability at temp. 103, 105, 85.6 °C, but at 91 °C, albumins, globulins, prolamins, and glutenins are denatured, so it further concluded that chia seed is a good composition of essential and non- essential amino acids. A comparison graph **Fig. 3** is plotted below between the protein content of Chia and soybean [27].



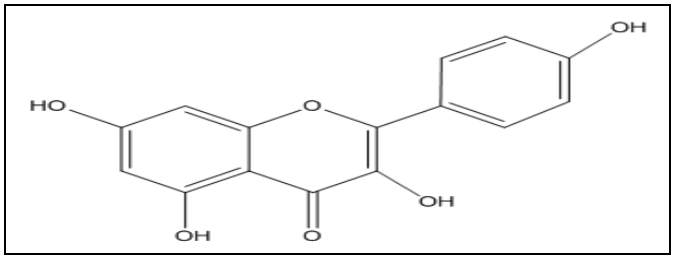
OMEGA-6-LINOLENIC ACID



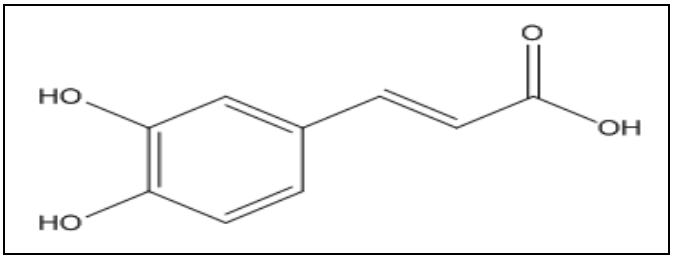
MYRICETIN



QUERCETIN



KAMPFEROL



CAFFEIC ACID

FIG. 2: THE MAIN ACTIVE CONSTITUENTS PRESENT IN *SALVIA HISPANICA* L.

Fibre Content: Fibre is one of the most important components of our food, as it is very beneficial for our health. Various surveys and literature have already mentioned that daily intake of fiber can reduce the risk of many diseases like cardiac disorders, diabetes mellitus type 2, and various types of cancers, and also dietary fiber consumption has been linked to an increase in post-meal satiety and the subsequent decreasing hunger [28].

ADA (American Dietetic Association) has mentioned that dietary fibers are very beneficial for health and have the potential for the prevention of diseases [29].

In literature, it is clearly mentioned that dietary fiber content in chia is approx 34-40g /100g, which is almost equal to 100% of the recommendation for adults, with the defatted fiber of 40 percent, soluble and mucilage in 5-10 percent [30]. In below **Table 4** it is clearly visible that chia consists of the high amount of fiber in comparison with others like quinoa, flaxseed, amaranth [31].

TABLE 4: FIBRE CONTENT OF CHIA AND OTHER GRAINS

Food	Fibre g/100 g
Chia	34.4
Flax Seed	27.3
Amaranth	6.7
Quiona	7.0
Almond	12.2
Peanuts	8.5
Soybean	9.6

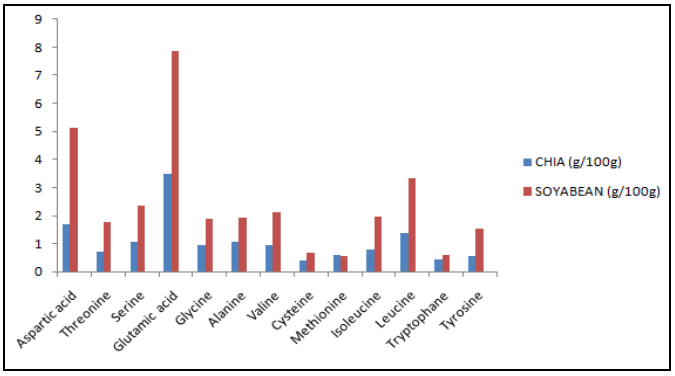


FIG. 3: COMPARISON GRAPH OF PROTEIN CONTENT BETWEEN CHIA AND SOYABEAN

Lipid Content: Chia is also a good source of lipid content, but the composition or ratio of fatty acid is somewhat different. According to USDA 2004, the ratio of palmic acid (16:0) to stearic acid (18:0) is 2:1, a ratio of oleic (18:1) to palmic acid (16:1) of monounsaturated fatty acids is 5:1 and ratio of linolenic acid (18:2) and polyunsaturated fatty acids (18:3) is **Table 5**. ALA is the major fatty acid that is present in a large amount approx 75% [32].

TABLE 5: AMOUNT OF INDIVIDUAL FATTY ACIDS PRESENT IN CHIA

Fatty acids	Quantity of individual fatty acids [% of total fat content]
Palmitic acid 16:0 9.66	7.10
Stearic acid 18:0	3.24
Oleic acid 18:1	10.53
ω-6 α-linolenic acid 18:2	20.37
ω-3 α-linolenic acid 18:3	59.76

Vitamins and Minerals: Vitamins and minerals are an essential component of our food as it helps to perform the normal function of our body system such as hormonal regulation, cell, and tissues differentiation, *etc.* [33] Also, it is very effective in oxidative stress. Chia seeds contain a very high amount of vitamin B. The amount of different types of vitamin B and other minerals are summarised in **Table 6** and **Fig. 4** [34].

TABLE 6: TOTAL AMOUNT OF VARIOUS TYPES OF VIT. B PRESENT IN CHIA

Vitamin B	Quantity (mg/g)
Thiamine	0.62
Riboflavin	0.17
Niacin	883
Folic acid	49

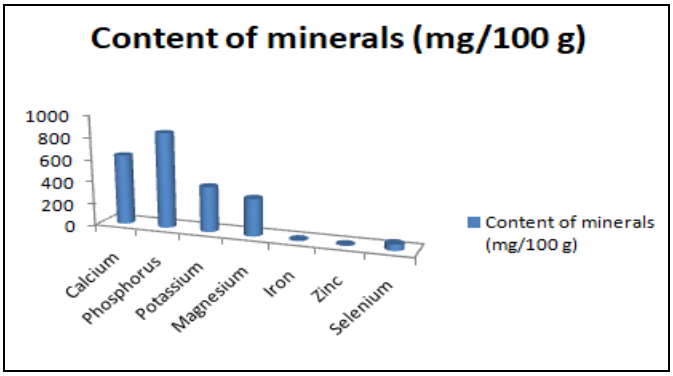


FIG. 4: A COMPARISON GRAPH OF QUANTITY OF DIFFERENT TYPES OF MINERALS PRESENT IN CHIA

Antioxidants: Anti-oxidants are those agents which prevent the oxidation process. Free reactive forms of oxygen like hydrogen peroxide, hydroxyl, and peroxide radicals are produced due to the transfer of electrons, and these free radicals are very harmful of human health as it becomes the reason of many neurological disorders and also causes inflammations. Chia seed is a huge source of antioxidants.

Here the lists of different antioxidants are mentioned [35]:

- Tocopherols
- Sterols (50% of ß-sitosterol)
- Protocatechuic acid
- Gallic acid
- p-coumaric acids
- caffeic acid
- epicatechin
- quercetin
- kaempferol

} polyphenolic compounds

Traditional Uses: In Mexico, there is a traditional use of the production of beverage and oils, which are used to intensify paint standards. Moreover, in the past, Chia seed was implemented for several uses, such as in the medicine it was ground to meal, also provided in drinks and pressed to oil. It will be counted in benefit if it is kept for a longer period of time (essential for travel). Along with that practical utilization, chia seed works better in Aztec blood. It was considered holy and used on religious occasions as a sacrifice [36].

The chia seed was considered as a supernatural food as per the ancient civilization. In Mayan "Chia" means "force," and mostly, it is similar to the huge amount of energy supplied by the chia seeds. The ancient warrior's endurance was attributed to the small seed. Still today, for some groups of people, this is applied. In the Mexico Tarahumara tribe, it is famous for its runners. Chia seeds, citrus fruit, and water are drunk by runners who are known as Iskiate. It is said that they can cover many miles after they have consumed chia water. Its record is actually worth our attention [37].

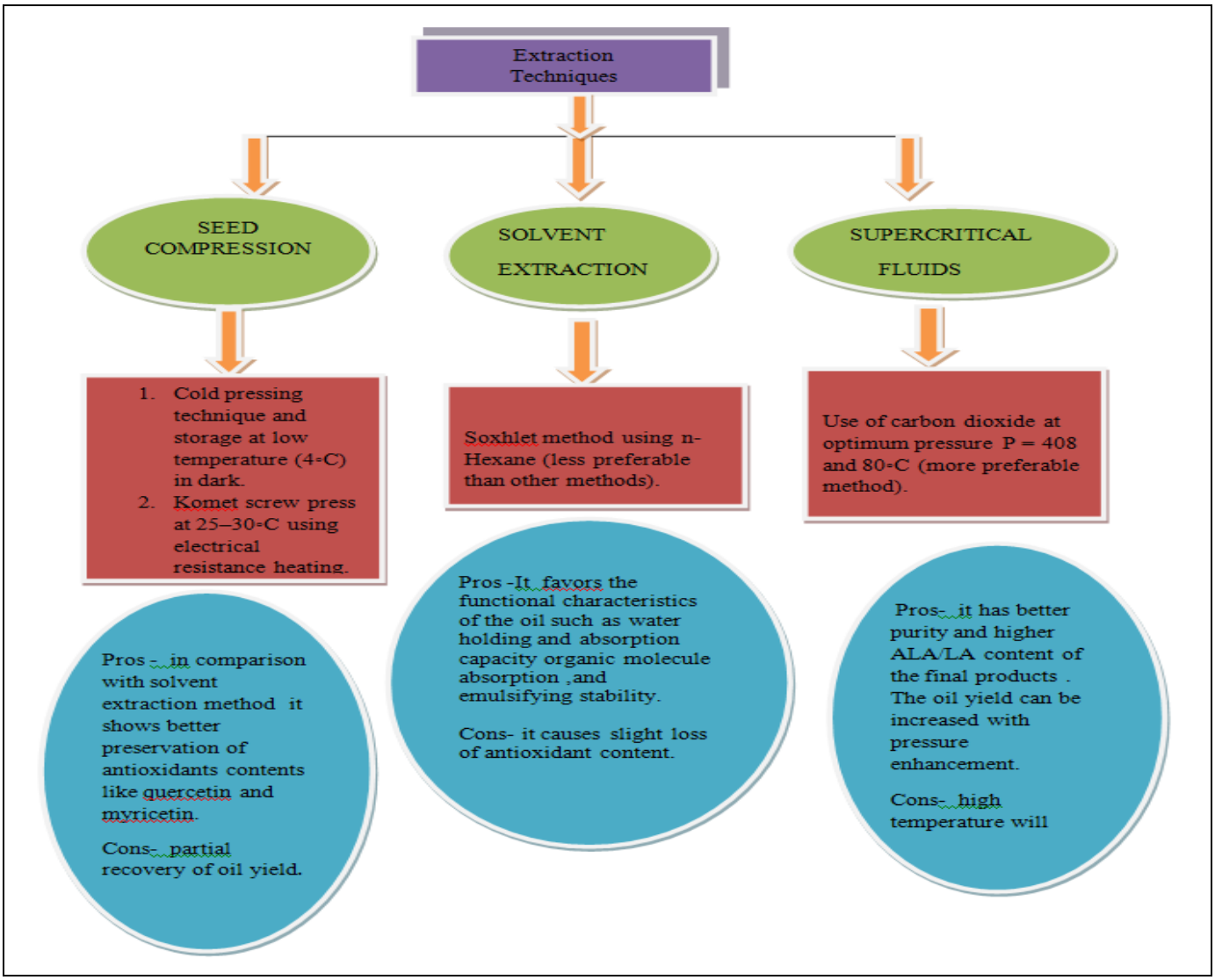


FIG. 5: DIFFERENT EXTRACTION TECHNIQUES OF CHIA SEED OIL

Present Uses:

Hypoglycaemic Effects: Bárbara Pereira da Silva *et al*., (2016) [38, 39] evaluated the effect of protein quality of chia on glucose level, lipid profile and working pattern of liver and intestine of Wistar rats by dividing it into two portions first untreated and the second one heated at 90 °C for 20 min. A certain no. of male rats were selected, and they were divided into six different groups having different diets like one received casein (control group), another one received a protein-free diet, and the remaining four received test diets that were chia seed; untreated chia and heated chia). This process was used for fourteen days, and after that, various protein ratio was calculated along with the determination of morphologies of liver and intestines. The values obtained from different protein ratio stated that the animals who were fed with chia have low glucose level, low triacylglycerides and low conc. of VLDL, LDL, HDL in comparison to another group also it was observed that the weight of the liver was lower than the control group and crypt depth and thickness of intestinal muscle layers were high. Therefore, it is proved that a regular intake of chia has better digestibility, hypoglycaemic effect better lipid profile and help to decrease the storage of fat in the liver and helps to increase the function of liver and intestine.

Ricardo Ayerza *et al*., (2005) [40] studied the effect of chia seed, which is a rich source of omega-3-ALA on cholesterol, triacylglycerol, lipid profile, *etc*. For this study, 24 male Wistar rats were selected, and they were divided into three groups and they were fed with corn oil, chia seed or chia oil, and this process was used for four weeks continuously. After four weeks blood samples of the rats were taken and analysed in which it was found that rats who were fed with chia seeds have reduced triacylglycerol content almost 3 and 2.5 times lower than other ones and also they found that there is an increase in the HDL level with increased x-3 fatty acid content. These results suggest that ALA-rich chia oil can act as an alternative for those people who are allergic to fish and also a better option for those people who are vegetarians.

Antihypertensive and Anti-oxidant Potential: Domancar Orona-Tamayo *et al*., [41] identified that chia protein is very effective for those people who are suffering from hypertension, and also it has been shown that chia is a good source of antioxidants and have a better ion chelating property. When there is a simulation in GIT digestion, we can observe that there is an automatic release of peptides.

After separation of protein by denaturing gel electrophoresis, it shows different protein profile, which proves that the amount of globulin is large along with albumin and they give highest antiradical activity against 2,2′-azino-bis(3-ethyl-benzothiazoline-6-sulphonic acid) (ABTS) and 2,2-diphenyl-1-picrylhydrazyl (DPPH) and also show inhibitory action for angiotensin-converting enzyme. Peptides from prolamin and globulin fractions showed the strongest ability to chelate the ferrous ion, and hence it is proved that chia seed has anti-hypertensive activity as well as it acts as an antioxidant.

Maira Rubi Segura Campos *et al*., (2013) [42] hydrolysation of protein fraction was performed with Alcalase–Flavourzyme and it was ultrafiltered through 4 molecular weight cut off membranes and then ACE-I inhibitory action was determined. The results proved that inhibitory action ranged from 53.84% to 69.31%, which proves that chia has strong blocking angiotensin –II production and have antihypertensive activity.

Anticancer Activities: In C.E. Espada *et al*., (2007) [43] *Salvia hispanica* (ChO) and *Carthamus tinctorius* (SaO) were vegetable oil sources of ω-3 and -6 PUFAs and a commercial diet as control (CO), were used. Analysis of fatty acids of neoplastic cells (NC) membranes by GLC; the eicosanoids 12- HETE and 12-HHT (LOX and COX metabolites) by HPLC and apoptosis and T-lymphocyte infiltration by flow cytometry and microscopy were done. NC from ChO groups showed lower levels of arachidonic acid and both eicosanoids compared to SaO and CO ($p<0.05$). The ChO diet decreased the tumor weight and metastasis number ($p<0.05$). Apoptosis and T-lymphocyte infiltration were higher, and mitosis decreased with respect to the other diets ($p<0.05$). Present data showed that ChO, an ancient and almost unknown source of ω-3, inhibits growth, and metastasis in this tumor model.

Post-menopausal Effects: FuxiaJin *et al*., (2012) [44] experiment was performed on 10 postmenopausal women of age approx 55.6 ± 0.8 years with BMI 24.6 ± 1.1 kg/m^2. 5g/day during a seven-weeks and after that their plasma samples were collected to measure the alpha-linolenic acid, eicosapentaenoic acid, docosapentaenoic acid, and docosahexaenoic acid and as a result, it was found that there is an increase in plasma alpha-linolenic acid, eicosapentaenoic acid, but there is no change in docosapentaenoic acid and docosahexaenoic acid.

Cardio Protection and Hepatoprotection: Hemant Poudyala *et al.,* (2012)[45] studied the cardioprotection and hepatoprotection properties of chia by performing experiments on rats. Treatment groups were given 5% chia seed for eight weeks. After treating them with a high-fat diet for eight weeks, and as a result, it was found that there was an improvement in insulin sensitivity, and glucose tolerance and also it was found that there was a decrease in visceral adiposity, hepatic steatosis and decreased cardiac and hepatic inflammation and fibrosis without any changes in plasma lipids or B.P.

Effects on Obesity: Luciana Tavares Toscano *et al.*, (2015) [46] evaluated the effect of chia supplementation in body composition, lipid profile, and blood glucose in overweight or obese individuals.

Methods: Men and women were randomly allocated in groups that ingested 35g of chia flour/day (CHIA; n=19; 48.8 ± 1.8 years) or placebo (PLA; n=7; 51.4 ± 3.1 years) for 12 weeks. Body composition and food intake were evaluated in every four weeks. Lipid profile and blood glucose were measured in the beginning and at the end of the study.

Results: Chia induced significant intragroup reduction in body weight (-1.1 ± 0.4kg; $p<0.00$), but without a difference when compared to PLA. Waist circumference reduced 1.9 ± 0.6 min CHIA group ($p<0.05$), but only in intragroup. It was observed a reduction in total cholesterol ($p=0.04$) and VLDL-c ($p=0.03$), and an increase in HDL-c ($p=0.01$) but only in the groups that ingested chia flour and presented abnormal initial values. Triglycerides, blood glucose, and LDL-C showed no changes for either group. It is concluded that the consumption of chia for 12 weeks promotes a significant but discrete reduction in weight and waist circumference and enhances lipid profile dependent on initial values.

Anti-diabetic Effects: Adriana G. Chicco *et al*., (2008) [47] investigated that daily consumption of chia is very beneficial in the case of diabetes as it is a very good source of omega 3-alpha –linolenic acid. For this study, two processes were developed, the first study of prevention of dyslipidemia and insulin resistance in Wistar rats who were fed with sucrose rich diet in which chia was present as fat for three weeks. The second one is the analysis of the effect of chia. Rats were fed with chia seed for three months, and at that period of time, dyslipidemia and insulin resistance were reported normal. After 3-5 months, half of the animals were continued with sucrose rich diet having chia as a fat source, and another half were given maize starch. The result which comes showed that rats who were given chia as diet had prevented the onset of dyslipidemia, and insulin resistance and glycemia didn't change. Secondly, rats having long term sucrose rich diets were normalized without having any change in insulinemia. Thus, it is proved that chia is very beneficial in the case of lipid and glucose homeostasis.

Effects on Immune System: Fernandez *et al*., (2008) [48] studied the effect of chia seed on the immune system of 23 days old Weanling male Wistar rats, the concentrations of thymus and serum IgE were used as an indicator of immunity. The trial was conducted for one month; rats were divided into three groups, one group was fed on chia seeds 150 (g/kg diet), the second group was fed on chia oil 50 (g/kg diet), while the third group was kept control. Diets of both groups were formulated in such a way that they had a similar concentration of alpha-linolenic acid and energy. After the termination of the feed phase, the body weights of all three groups were measured after four hours of fasting, and blood was analyzed for serum IgE concentration (mg/ml). The results evidenced no difference in body weight and IgE when chia was administered in seed or oil form. The concentration of IgE was considerably higher in both the groups as compared to the control. Inclusion of chia in any form did not induce any symptom of abnormal behavior, diarrhea,

dermatitis, supplementation of diets with other sources of omega-3 fatty acids such as flaxseed or marine products usually results in allergy, fishy flavor, problems of the gastrointestinal tract, diarrhoea, *etc*.

Extraction of Chia Seed Oil: Chia oil extraction method is very important as it can lead to variation in the quantity as well as the quality of the oil [49-51]. Different methods are being used to extract the oil content from the seed of chia, *e.g.*, seed compression technique, solvent method, etc. in which each and every technique has its own pros and cons. In the below chart, different extraction techniques of chia seed oil are summarised **Fig. 5**.

Market Demand and Commercial use of Chia Seed: Today, the demand for functional foods has increased a lot; this is happening due to the increasing number of people suffering from many diseases like CVS, diabetes, obesity, *etc*. These conditions have been arising due to bad day to day routine and inappropriate balanced diet. People are consuming saturated fatty acids in a very high amount, which is not very beneficial for health. Many kinds of literature have already mentioned that the occurrence of cardiac-related problems is due to a high intake of saturated fatty acid, especially palmitic acid and low consumption of PUFA.

Earlier, people were consuming these functional foods on a daily basis. Now, many types of research are going on to increase the potential of these functional foods. Nowadays, chia has gained huge popularity due to its oil content as it has a high amount of PUFA. Chia, which was native to Mexico and Guatemala, is now also used by people of other countries. Now, its cultivation is not only limited to America, but it has been extended in other countries, *e.g.*, Australia has become the faster producer of chia. The main reason why chia is gaining popularity in the market is because of its high content of omega-3-apha linolenic acid and anti-oxidative properties [52-55].

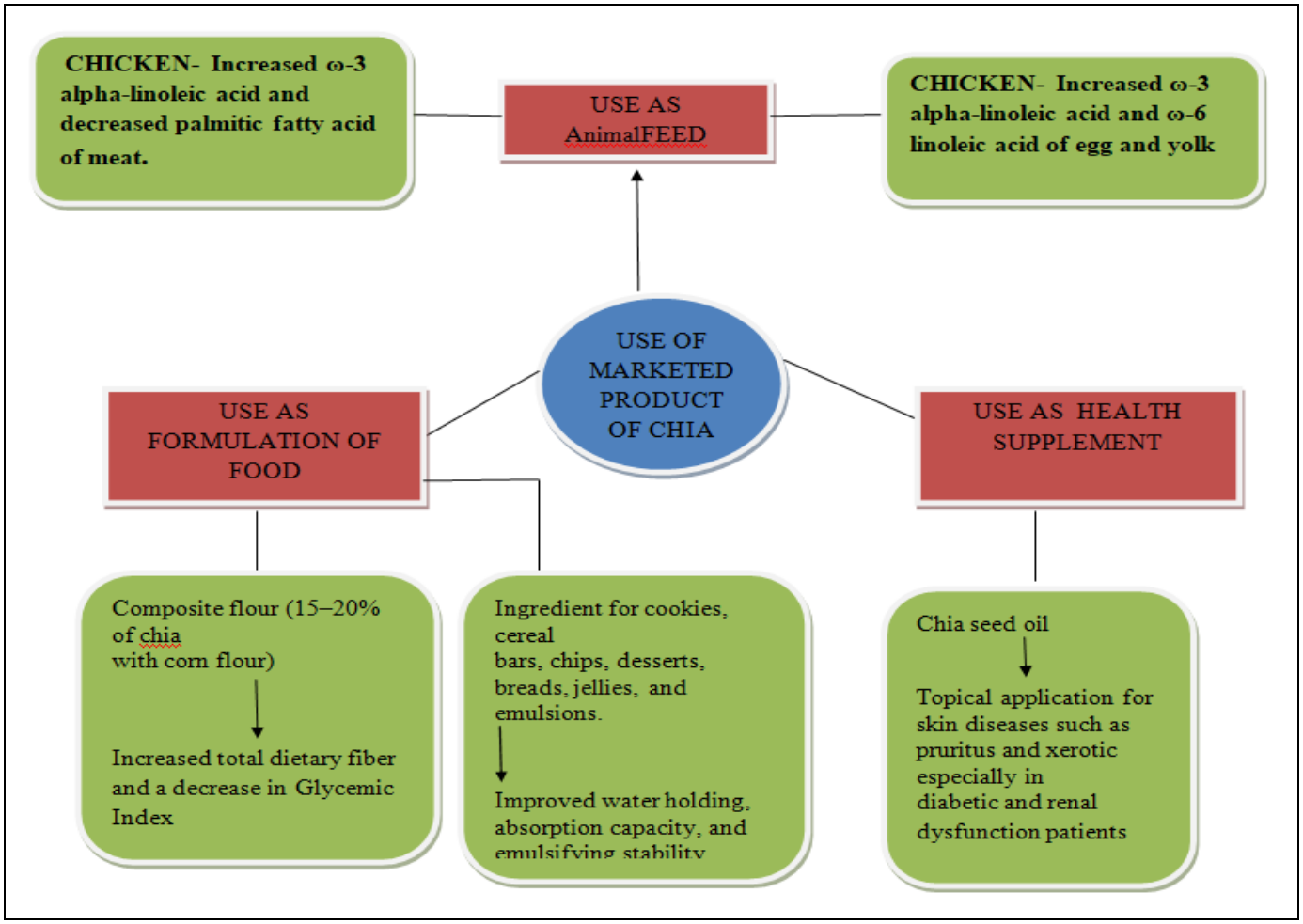


FIG. 6: DIFFERENT TYPES OF USE OF MARKETED PRODUCT OF CHIA

In the present scenario, chia seed is used as a healthy oil supplement for both humans as well as animals. According to the United States, Dietary Guidelines (2000) chia may be used as a primary food but not exceedingly more than 48g/day. Nowadays, chia is consumed in the form of salad, in beverages, cereals, or sometimes it can be eaten as raw [56]. The EU Commission has already given its approval about the amount of chia seed used in bread products with a limit of not more than five percent. Many other countries like the US, Canada, Chile, New Zealand, Australia, and Mexico have used chia for so many different applications *e.g.*, bars, breakfast cereals, cookie snacks, fruit juices, cake, and yogurt [57]. In spite of chia's well-known properties of an antioxidant and its healthy fatty acid profile, many people are still unaware of its benefits. The argentine economy is very much depending upon chia seed production as it has a 24% contribution in the agricultural industry [58-59]. In the 2008 report, it is mentioned that Argentina contributed approx. 4% of world grain production. Although there are still some problems related to the productivity and sustainability of chia exists in the global market. The current planting and production of chia seed oils are yet to fully meet the world market demand. In the below chart, different commercial use of chia around the globe is mentioned **Fig. 6.**

CONCLUSION: Chia is native to Mexico and the southwestern part of Latin America. It was used as a beverage, medicines in ancient times, and also it has a huge religious value. Chia seed is a high packet of nutrition like protein, fibers, lipids, vitamins and minerals, and antioxidants. Also, it is very beneficial in the treatment of many diseases because of its oil content (omega-3 ALA). Therefore, chia can be used for the prevention of many diseases like CVS, arthritis, and many more, and it can provide a healthy life to peoples.

In the above section, the beneficial part of chia is already mentioned, and from that, it is crystal clear that in near future demand of chia will increase, and it will gain huge popularity among people as well as researchers and many other studies can be done on it.

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CONFLICTS OF INTEREST: There is no conflict of interest in this manuscript.

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