EXTRACTION AND EVALUATION OF STONE FRUIT KERNEL OILS

Thesis

by

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Dedicated

to my

Revered Parents

and

Pari

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CERTIFICATE – 1

This is to certify that the thesis entitled **"Extraction and evaluation of stone fruit kernel oils"** submitted in partial fulfilment of the requirement for the award of degree of **MASTER OF SCIENCE in HORTICULTURE (POSTHARVEST TECHNOLOGY)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.) is a bonafide research work carried out by **Mr. Prashant Kamboj (H-2000-13-M)** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigations have been fully acknowledged.

Place : Nauni, Solan
Date : 27 September, 2002

27/09/02

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CERTIFICATE – II

This is to certify that the thesis entitled **"Extraction and evaluation of stone fruit kernel oils"** submitted by **Mr. Prashant Kamboj (H-2000-13-M)** to Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Solan (H.P.), in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE in HORTICULTURE (POSTHARVEST TECHNOLOGY)** has been approved by the Student's Advisory Committee after an oral examination of the same in collaboration with the external examiner.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

1

INTRODUCTION

It is a paradox that India having largest acreage under oil seeds still depends upon the imports to meet its bare minimum demands of edible oils. The per capita consumption of edible oils in our country is 7-8 Kg/head/year against a world average of 12 Kg/head/year, while per capita consumption of fats and oils in developed countries is as high as 30-40 Kg/head/year. It is in this context that the Technology Mission on Oil seeds (TMO) was launched by government of India in 1986 to improve the production and productivity of conventional oil seeds to promote some alternative oil crops (TMO, 1987). Utilization of some tree born crops like fruits and their kernels for extraction of oils is an important resource, which is still untapped in our country. Realizing the importance, the Technology Mission on Oil seeds (TMO) has predicted a theoretical potential of about 5.5 million tonnes per annum of oil from forest tree born oil seeds (TMO, 1989).

Stone fruits belonging to family Rosaceae (sub-family Prunoideae) includes several important crops such as peach, plum, apricot, cherries, nectarines etc. Among these, peach, plum and apricots are grown extensively in USA, Spain, France, Italy, Turkey, Morocco, Iran, Africa and Australia. In India, these are grown in Jammu & Kashmir, Himachal Pradesh, sub-mountainous tracts of Punjab, Uttranchal, North Eastern states and to a limited extent in the Nilgiris. These fruits are mostly used for table purpose or processed to prepare various types of value added products. The stones/pits left after processing usually possess no commercial value and are treated as waste product, but can be used as a very good source of oil. During the year 2001, India produced 1,97,400 tonnes of peach, plum and apricot against the world production of 25 million tonnes (FAO, 2001). In Himachal Pradesh alone, the production of important stone fruits, excluding wild fruits has been recorded to be

11,184 tonnes (Anon, 2000). Among different stone fruits *Chulli* (wild apricot) cultivar of apricot, *Santa Rosa* cultivar of plum and *Elberta & July Elberta* cultivar of peach are extremely grown in the state and are used for various processing purposes. Though the pulp of these fruits is used for the manufacture of various processed products (canned produce, jams, squashes, chutney etc.), yet the stone goes as waste. For instance during canning of peaches and apricots, stones worth thousands of tonnes are thrown annually in Himachal Pradesh alone, the kernel of which is known as a potential source of oil for edible and/or industrial purposes.

Among various stone fruits, kernels of wild apricot (*Chulli*) are used extensively by the local people for the extraction of oil in some parts of Kinnaur, Lahaul and Spiti and Shimla areas in Himachal Pradesh and Uttarkashi regions of Uttaranchal for use as food, massaging and for other home made remedies. In view of good potential, large area is still being brought under cultivation of wild apricot in many parts of Uttarkashi in Uttaranchal state (Anon, 1994). Similarly, wild peach (*Behmi*) stones are also used for oil extraction purposes in some parts of Uttaranchal and Himachal Pradesh. It is in this context that stone fruit kernels need to be evaluated for their use as a source of oil.

Further, the stone fruit kernel oil is considered to be a good source of essential fatty acids like oleic and linoleic acids and commands good nutritional and pharmaceutical importance. However, crushing of stones (decortication), kernel separation from the crushed mass and availability of suitable machinery for oil extraction are the practical problems for making the technology a commercial venture. Besides the separated fruit kernels and its oils are known to possess a cyanogenetic glucoside ' amygdalin' ($C_{20}H_{27}NO_{11}$) which upon hydrolysis yield hydro-cyanic acid (HCN). Due to the water-soluble nature, sometimes HCN also get extracted in the oil for which there is a need to develop a method for its removal from oil to make it suitable for food and feed purposes.

However, the information available on evaluation of suitability of different fruit kernels viz. peach, plum and apricot for extraction of oils and its use for various food and feed purposes is scarce in literature. Therefore, the present investigations on the development of suitable technology for decortication, kernel separation, detoxification, oil extraction, quality evaluation and further use of oil extracted from various fruits viz, peach, plum and apricot for different purposes have been undertaken with the following main objectives:

1. To evaluate the quality of oil from kernel of different stone fruits viz, peach, plum and apricot.
2. To develop a commercial method for decortication, kernel separation and oil extraction from different fruits.
3. To isolate and characterize the toxic principle in different kernels/oils and standardize method for detoxification.
4. To study the storage stability of extracted oils from apricot, peach and plum kernels.

REVIEW OF LITERATURE

2

REVIEW OF LITERATURE

Tree borne fruits and their kernels are an important source of oil which is still untapped in India. Further, utilization of large quantities of stones/pits left after processing of stone fruits for oil extraction not only supplements the processor's income but also reduces environmental pollution. Except for few solitary reports on chemical characteristics of oil from some stone fruit kernels, no systematic work has been reported in the literature. Nevertheless, the little work conducted on different aspects of kernel oil extraction viz., physico-chemical composition of fruit, stone, kernel and oil, decortication, kernel separation, removal of toxic principle and changes during storage etc. has been reviewed as under:-

2.1 PHYSICAL CHARACTERISTICS

Apricot, peach and plum are the important stone fruits whose physical characteristics have been described to be quite variable. According to Westwood (1993) the fruits of peaches are variable in size, shape, colour of skin and flesh; glabrous usually with fuzzy skin; flesh juicy, sweet or mildly sub-acidic; stone large, free or clinging, deep pitted, sometimes corrugated, sutured and hard. While, the fruits of plums have been characterized as medium to large, oval or round in shape, red to dark blue in colour, with firm flesh, taste- from sweet to sub-acid and good in flavour (Mitra *et al*, 1991). The apricots on the other hand have been reported to be round in shape, pubescent with yellow skin overlaid with red, flesh yellow to yellowish orange, firm and sweet, mostly free from flat, rigid stone (Sharma, 2000). The stones/pits of peach constitute as high as 30-35 per cent of the total fruit weight (Anon., 1976) as against 6-11 per cent in apricot (Dhar and Chauhan, 1963) whereas plum pits account for only 2.3-6.0 per cent of the total fruit weight (Winton and Winton, 1950). Similarly, the presence of kernels in different stones is also quite variable. Tilgner

(1931) reported that the stones of peaches yield 7 per cent kernels, those of plum 12 per cent and apricot 22-25 per cent. According to Dhar and Chauhan (1963) the peaches and apricots grown in Kumaon region contain 8.9 per cent and 38 per cent kernels respectively. Similarly, Abd El-Aal *et al.* (1986) reported 31.2 per cent kernels in apricot pits. Wild apricot pits were also recorded to yield 30 per cent kernels (Aggarwal *et al.*, 1974). *Morpankha* and *Chawaru* cultivars of apricots grown in Kumaon region on the other hand yielded 20-21 per cent and 25-25 per cent kernels (Dang *et al.*, 1964). Kamalov (1990) reported that the local varieties of apricot grown in Central Tadzhikistan had a high kernel recovery of 35-41 per cent. Whereas Kapoor *et al.* (1987) reported 13.5-32.7 per cent kernel yield in apricot varieties of Ladakh region. Thus the kernel yield in stones of different fruits varied between 13.5 to 41 per cent in apricot, 7-8.9 per cent in peaches and 12-26.7 per cent in plums.

The oil yield from the fruit kernel of peach and plum varied between 32-45 % and 39-42 % respectively (Winton and Winton, 1950). Anon., (1976) reported that *Alubukhara* cultivar of plum gave 39.1 per cent of light yellow non-bitter oil with pleasant odour and taste. Abd El-Aal *et al.*, (1987) reported an oil yield of 36.9 and 41.1% in kernels of *Beauty* and *Clymax* cultivar of plums grown in Egypt. This oil resembled that of almond oil. According to Dhar and Chauhan (1963) peaches and apricots of Kumaon region contained 43.6 per cent and 33.3 per cent oil while Gutfinger *et al.* (1972) recorded a value of 30 and 23 per cent lipids in apricot and peaches respectively. Saadany *et al.* (1994) reported an oil yield of 49.58 per cent in peach kernel oil whereas Rahma and Abd El-Aal (1988) reported a higher oil yield of 54.5 per cent in peaches. Hinnawy *et al* (1978) obtained an oil yield of 33.67% from pulp of peach kernels. *Morpankha* and *Chawaru* cultivar of apricot however, yielded as high as 44.21% and 44.55% oil in their kernels respectively (Dang *et al.*, 1964). Aggarwal *et al.* (1974) reported an oil yield of 40.42 per cent in wild apricots. In apricot kernels, the oil yield reported by various workers was 48%, 50.90 % in apricots grown in Egypt (Hallabo *et al.*, 1977 and Abd El-Aal *et al.*, 1986); 27.7% in *Koban* cultivar and 66.67% in *Sufaidi* cultivar of apricot grown in Ladakh (Kapoor *et al.*, 1987); 52% in apricot kernels of cultivar *Moorpark* (Beyer and Melton, 1990); 59.6-60.2% in local apricots grown in Tadzhikistan (Kamolov, 1990); 46.5% in *NJA-13* apricot cultivar grown in Pakistan (Sherin *et al.*, 1993); 53.2% in apricot kernels of *Novosadka 2* cultivar grown in European region (Duric and Vracar, 1994); and 49%

in processing waste of apricot (Iordanidou *et al.*, 1999). Thus the yield of oil in the kernels of different fruits ranged between 27.7 to 66.7 % (apricots); 23-54.5 % (peach) and 32-45% in plums.

2.2 PHYSICO-CHEMICAL CHARACTERISTICS

2.2.1 Fatty acid composition

The kernel oils from apricot, peach and plum mostly consist of unsaturated fatty acids, such as, oleic and linoleic acid which contribute up to 90 per cent of total oil yield. The presence of these fatty acids in kernel oils is reported to increase the low-density lipoprotein receptor activity for the regulation of cholesterol in plasma (Dietschy, 1997 and 1998). Therefore, these oils are considered to possess good nutritional and pharmaceutical importance. In kernel oils of different fruits, the fatty acid composition comprised of myristic acid – 3.8 per cent, lauric acid - 0.9 per cent, stearic acid – 0.6 per cent, palmitic acid – 0.6 per cent, arachidic acid - 5.5 per cent, oleic acid -65.2 per cent and linoleic acid - 19.8 per cent in plums (Anon., 1976) and palmitic acid - 4.37 per cent, plamitoleic acid – 0.12 per cent, stearic acid – 0.46 per cent, oleic acid - 66.29 per cent, linoleic acid – 28.64 per cent and linolenic acid - 0.12 per cent in apricots (Abd El-Aal *et al.*, 1986). According to Aggarwal *et al.* (1974) wild apricot oil mainly consists of palmitic acid – 4.1 per cent, oleic acid - 74.3 per cent and linoleic acid - 21.6 per cent. Similarly, the *Morpankha* and *Chawaru* cultivar of apricot grown in Kumaon region had respective fatty acid composition comprising of myristic acid –1.29 and 1.10 per cent, palmitic acid - 4.11 and 3.50 per cent, stearic acid - 2.07 and 1.98 per cent, oleic acid – 69.30 and 73.38 per cent and linoleic acid - 23.33 and 20.04 per cent (Dang *et al.*, 1964). According to Cruess (1958), the bitter kernels of apricot obtained after refining were light pale yellow in colour and contained the fatty acid composition consisting of myristic acid – 1.1 per cent, palmitic acid – 3.5 per cent, stearic acid – 2.0 per cent, oleic acid – 73.4 per cent and linoleic acid – 20.0 per cent. Iordanidou *et al.*(1999) reported a fatty acid mixture of lauric acid – 0.12%, palmitic acid – 4.62%, stearic acid – 0.31%, arachidic acid – 0.11%, palmitoleic acid – 0.72%, oleic acid – 68.91% and linoleic acid – 25.21% in apricot kernel oil. Sherin *et al.* (1993) recorded a fatty acid mixture of oleic acid –

68.88 per cent, linoleic acid – 15.77 per cent, caproic acid – 8.19 per cent and small amounts of other fatty acids in *NJA-13* cultivar of apricot in Pakistan. Hallabo *et al.* (1977) also recorded the presence of about 90 per cent of oleic and linoleic acid in apricot kernel oil but in case of peach, fatty acid mixture of palmitoleic acid – 0.04 per cent, oleic acid – 68.92 per cent, linoleic acid - 21.15 per cent, gadoleic acid – 0.23 per cent, eicosatrienoic acid – 0.48 per cent, myristic acid – 0.06 per cent, palmitic acid – 6.80 per cent and arachidic acid – 1.20 per cent was reported (Saadany *et al.*, 1994). Whereas, according to Rahma and Abd El-Aal (1988) peach kernel oil contained myristic acid – 0.88 per cent, palmitic acid – 13.4 per cent, stearic acid – 6.41 per cent, palmitoleic acid – 0.16 per cent, oleic acid 63.8 per cent and linoleic acid – 15. 4 per cent. Thus, the fatty acid composition of fruit kernel oil is composed mainly of oleic (50.95-83.3 per cent) and linoleic acid (10.24 – 45.90 per cent).

2.2.2 Refractive Index

The refractive index is the degree of deflection of the beam of light that occurs when it passes from one transparent medium to another. The refractive index of fats and oils is useful for their identification and testing their purity. Generally the refractive index of oil decreases as the temperature rises; however, it increases with increase in the length of the carbon chain, as well as, with the increase in the degree of unstauration. Thus, in terms of fats and oils, more the degree of unsaturation, more will be the refractive index (Nawar, 1985). According to Eckey (1954), the refractive index in peach, plum and apricot kernel oil ranged between 1.462 – 1.465. Rahma and Abd El-Aal (1988) and Saadany *et al.* (1994) recorded a value of 1.4695 in peach kernel oil. However, Dang *et al.* (1964) recorded a value of 1.471 and 1.472 refractive index in plum and apricot kernel oils respectively. The refractive index reported by various workers in different samples of apricot oil was 1.4638 (Anon., 1976); 1.4633 (Abd El-Aal *et al.*, 1986); 1.465 in wild apricot kernel oil (Aggarwal *et al.*, 1974) and 1.4672 – 1.4689 in different varieties of apricot of Ladakh region (Kapoor *et al.*, 1987).

2.2.3 Specific gravity

Eckey (1954) recorded a specific gravity of 0.911 – 0.916, 0.912 – 0.916 and 0.913 – 0.918 in oils from plum, apricot and peach kernels. The specific gravity measured by various workers in kernel oil of different fruits was 0.912 in plum and 0.915 in apricot (Anon., 1976); 0.914 and 0.9158 in peach (Saadany *et al.*, 1994 and Rahma and Abd El-Aal, 1988); 0.9136 in apricot (Abd El-Aal *et al.*, 1986); 0.917 in wild apricot (Aggarwal, 1974); and 0.9275 and 0.9281 in peaches and apricots of Kumaon region (Dhar and Chauhan, 1963). Dang *et al.* (1964) recorded a specific gravity value of 0.9230 and 0.9154 in *Morpankha* and *Chawaru* cultivars of apricot grown in Kumaon region. However, in general, either the unsaturation of fatty acid chain or increase in chain length of the fatty acid residue tends to increase the specific gravity of the oil (Meyer, 1987).

2.2.4 Iodine value

The iodine value is a measure of the degree of unsaturation of an oil or fat. More the unsaturation more it is useful for consumption for people having cardiac problems (Spiller *et al.*, 1990 and Chisholm *et al.*, 1998). The fatty acid composition in natural fats is fairly characteristic of the fat. While, there can be variations in each vegetable oil with climate, soil and variety, yet, the variations are small compared to the variation between fats. The iodine value is therefore of great value in identifying fats and oils (Meyer, 1987). It is also a useful parameter in studying oxidative rancidity of oils since higher the unsaturation, the greater the possibility to go rancid (Thimmaiah, 1999). The decline in iodine value is also used to monitor the reduction of dienoic acid during the course of auto-oxidation (Nawar, 1985). Eckey (1954) reported an iodine value of 95 – 110, 100 – 110 and 97 – 109 in kernel oils from peach, plum and apricot. The iodine value determined in kernel oil of different fruits was 91 and 100 in plums and apricots respectively (Anon., 1976); 85.58 and 87.2 in peaches and apricots respectively (Dhar and Chauhan, 1963); 104 and 84.2 in peach kernel oil (Saadany *et al.*, 1994 and Rahma and Abd El-Aal, 1988); and 103.8 in apricot kernel oil (Abd El-Aal *et al.*, 1986). Further, the *Morpankha* and *Chawaru* cultivars of apricot in Kumaon region and varieties grown in Ladakh region were reported to contain 109.90, 99.58 and 80.82, 123.0 iodine values respectively (Dang *et* *al.*, 1964 and Kapoor *et al.*, 1987). The wild apricot kernel oil on the other hand had an iodine value of 104.1 (Aggarwal *et al.*, 1974).

2.2.5 Saponification value

Saponification is the process by which the fatty acids in the glycerides of the oil/fat are hydrolyzed by an alkali. The resultant salts of fatty acids are called as soaps. When the oil or fat is heated with potassium hydroxide, it is saponified and releases fatty acids and glycerol. Each molecule of triglyceride uses three molecules of potassium hydroxide for saponification. Saponification value is the number of milligrams of potassium hydroxide required to saponify the fatty acids resulting from the complete hydrolysis of one gram of fat or oil. This value gives an indication of the nature of the fatty acid in the fat, since the longer the carbon chain, the less acid is liberated per gram of the fat hydrolysed. Thus, this value is useful for a comparative study of the fatty acid chain length in the oil (Thimmaiah, 1999). According to Eckey (1954) the saponification values in kernel oil of peach, plum and apricot range between 189 – 194, 188 – 195 and 188 – 200 respectively, while Anon., (1976) recorded a saponification value of 192 and 194 in plum and apricot kernel oils respectively. Further, saponification value of 186 and 192 was reported in peach kernel oil (Saadany *et al.*, 1994 and Rahma and Abd El-Aal, 1988). Abd El-Aal *et al.* (1986) recorded a value of 189.7 saponification value in apricot kernel oils. Similarly, *Morpankha* and *Chawaru* cultivars in Kumaon region were found to register the figure of 191.3 and 193.8 saponification value (Dang *et al.*, 1964) while wild apricot kernel oil showed the presence of slightly lower (188.8) level of saponification value (Aggarwal, 1974).

2.2.6 Acid value

The acid value is the number of milligram of the potassium hydroxide required to neutralize the free fatty acids present in one gram of fat. The amount of free fatty acids gives an indication of the age and quality of fat. A small quantity of free fatty acids is usually present in oil along with triglycerides. However, its concentration increases with storage. The keeping quality of oil therefore, relies upon the free fatty acid contents (Thimmaiah, 1999). According to Eckey (1954) the acid value in kernel oils of peach, plum and apricot stones generally range between 0.4 – 3.0, 0.5 – 3.0 and 0.2 – 4.0 respectively. However, wide variations have been recorded in acid values of kernel oils from different fruit stones. Anon., (1976) reported an acid values of 1.2 and 20.1 in plum and apricot kernel oils. Dhar and Chauhan (1963) found acid values of 9.5 and 1.07 in peaches and apricot; Dang *et al.* (1964) detected as high as 27.14 and 20.10 acid values respectively in *Morpankha* and *Chawaru* cultivars of apricot grown in Kumaon region. However, Abd El-Aal *et al.* (1986) could find only 0.12 acid values in apricot. Wild apricot on the other hand showed the presence in its kernel oil of 3.6 acid values (Aggarwal *et al.*, 1974). In almond and walnut kernel oils the acid value have been recorded as 0.5 – 3.5 and 2.5 respectively (Meyer, 1987). However, according to Indian Food Laws, the acid value in almond oil shall not exceed 6.0 (Anon., 1996).

2.2.7 Peroxide value

When lipids contain unsaturated fatty acids, oxidation takes places at the unsaturated linkages. The process of oxidative degradation of oil gives rise to volatile aldehydes, which imparts a characteristic rancid odour. A measure of oxidative rancidity is the peroxide number, which is expressed as milli-equivalents of peroxide per Kg of lipids. Therefore, peroxides are the main initial products of auto-oxidation and can be measured by various methods based on their ability to liberate iodine from potassium iodide or to oxidize ferrous to ferric ions. Although, peroxide values are applicable to peroxide formation at the early stages of oxidation, it is nevertheless, highly empirical as it varies with procedure of estimation and changes in temperature. During the course of oxidation, peroxide value reaches the peak and then declines (Anon., 1980). In apricot kernel oil the peroxide value has been found to be only 0.12 (Abd El-Aal *et al.*, 1986). Various unsuccessful attempts have been made to correlate peroxide value with the development of rancid flavour. However, mainly owing to the reason that the amount of oxygen that must be absorbed or peroxides that must be formed to produce rancidity vary with the composition of the oil (the more saturated fats need less oxygen absorption to become rancid), the presence of anti-oxidants and trace metals and conditions of oxidation (Nawar, 1985).

2.2.8 Hydro-cyanic acid (HCN)

Cyanogenetic glucosides yielding hydro cyanic acid upon hydrolysis are widely distributed within approximately 150 plant species. Amygdalin (Benzaldehyde cyanohydrin glucoside), probably the first known of this complex glucoside is present in the kernels of stone fruits and was first isolated from the seeds of bitter almond (Liener, 1966). The lethal dose of HCN for human is estimated to be 0.5 – 3.5 mg per kg body weight and occasionally sufficient quantities of cyanogenetic foods are consumed to cause fatal poisoning in humans. Although, accidental cyanide poisoning from consumption of stone fruit kernels is not frequently reported, actual poisoning especially of children is a worldwide occurrence (Sayre and Kaymakcalan, 1964). Apparently many people like the taste of raw kernels. In addition, apricots, peach and cherry kernels have been utilized extensively in Germany and United States for the manufacture of fixed oils, bitter almond oils and macroon paste (Cruess, 1958). Thus, the possibility of the chronic toxicity resulting from regular consumption of low levels has been suggested but not yet proved (Wogan and Marletta, 1985). In different fruit kernels, varying levels of amygdalin and hydro–cyanic acid has been recorded. According to Winton and Winton (1950) an HCN content of 0.06 per cent was recorded in plum kernels. In apricots, the HCN content was also found to be 0.06 per cent (Anon., 1976). However, Aggarwal *et al.* (1974) reported an amygdalin content of 4.3 per cent in wild apricot kernels. Stosic *et al.* (1987) conducted toxicological tests on mice and found that peach, plum and apricot contains 102.66 mg %, 75.65 mg % and 8.10 mg% HCN respectively as the toxic component. Earlier Holzbecker *et al.* (1984) reported that apricot and peach seeds respectively contain 2.92 mg per gram and 2.60 mg per gram HCN in their kernels. Similarly, Stoewsand *et al.* (1975) have shown the presence of 11.7, 177.1, 143.5, 164.0 and 132.5 mg HCN per 100 gram of kernels in *Moorpark, Summerland 4E-55-9, Veecot, Viceroy and Vineland 51175* cultivars of apricot respectively. However, *Amar* cultivar of apricot did not show presence of any HCN in its kernels (Abd El-Aal *et al.*, 1986). Thus, the extent of presence of HCN also varies with the type of fruit, variety and method of extraction of oil.

2.3 DECORTICATION (CRUSHING) OF STONES/PITS

Decortication is the method of breaking the stones/pits of stone fruits or nuts of nut fruits to separate the kernels. It can be performed either manually or by using a mechanical device called decorticator. Reddy *et al.* (1995) in Oil Technological Research Institute, Anantpur developed a hand-operated decorticator for apricot nuts. However, the possibility of using the decorticator in breaking of hardy stones like peach, plum, cherry etc. is yet to be explored and information on this aspect is lacking in the literature.

2.4 KERNEL SEPARATION

The separation of kernels from the crushed mass of stone fruits is quite laborious and time consuming work especially in peaches where the percentage of kernels is very less as compared to the stones/pits of other fruits viz., apricot, peach, plum, prunes etc. Schab and Yannai (1973) separated apricot kernels from crushed mass using a salt solution of specific gravity 1.115. Further no systematic work for separation of kernels from decorticated/crushed mass has been done and information in this aspect is lacking in the literature.

2.5 OIL EXTRACTION

The oil from the oil seeds and fruit kernels is extracted either by solvent extraction or by using oil press or oil expeller. The per cent oil yield is more in solvent extraction method but the cost incurred is also much more. The oil yield by the solvent extraction method was found to be 50.90 per cent in *Amar* variety of apricot (Abd El-Aal, 1986); but the oil expressed by the means of oil press was found to be only 40.42 per cent in wild apricot kernel oil (Aggarwal *et al.*, 1974). In kernels of plums and peaches the oil yield has been reported to vary between 39 – 42 per cent in plums (Anon., 1976) and 32 to 45 per cent in peaches (Winton and Winton, 1950). However, not much information is available on the development of commercial method of oil extraction from stone fruit kernels.

al., 1964 and Kapoor *et al.*, 1987). The wild apricot kernel oil on the other hand had an iodine value of 104.1 (Aggarwal *et al.*, 1974).

2.2.5 Saponification value

Saponification is the process by which the fatty acids in the glycerides of the oil/fat are hydrolyzed by an alkali. The resultant salts of fatty acids are called as soaps. When the oil or fat is heated with potassium hydroxide, it is saponified and releases fatty acids and glycerol. Each molecule of triglyceride uses three molecules of potassium hydroxide for saponification. Saponification value is the number of milligrams of potassium hydroxide required to saponify the fatty acids resulting from the complete hydrolysis of one gram of fat or oil. This value gives an indication of the nature of the fatty acid in the fat, since the longer the carbon chain, the less acid is liberated per gram of the fat hydrolysed. Thus, this value is useful for a comparative study of the fatty acid chain length in the oil (Thimmaiah, 1999). According to Eckey (1954) the saponification values in kernel oil of peach, plum and apricot range between 189 – 194, 188 – 195 and 188 – 200 respectively, while Anon., (1976) recorded a saponification value of 192 and 194 in plum and apricot kernel oils respectively. Further, saponification value of 186 and 192 was reported in peach kernel oil (Saadany *et al.*, 1994 and Rahma and Abd El-Aal, 1988). Abd El-Aal *et al.* (1986) recorded a value of 189.7 saponification value in apricot kernel oils. Similarly, *Morpankha* and *Chawaru* cultivars in Kumaon region were found to register the figure of 191.3 and 193.8 saponification value (Dang *et al.*, 1964) while wild apricot kernel oil showed the presence of slightly lower (188.8) level of saponification value (Aggarwal, 1974).

2.2.6 Acid value

The acid value is the number of milligram of the potassium hydroxide required to neutralize the free fatty acids present in one gram of fat. The amount of free fatty acids gives an indication of the age and quality of fat. A small quantity of free fatty acids is usually present in oil along with triglycerides. However, its concentration increases with storage. The keeping quality of oil therefore, relies upon the free fatty acid contents (Thimmaiah, 1999). According to Eckey (1954) the acid value in kernel oils of peach, plum and apricot stones generally range between 0.4 – 3.0, 0.5 – 3.0 and 0.2 – 4.0 respectively. However, wide variations have been recorded in acid values of kernel oils from different fruit stones. Anon., (1976) reported an acid values of 1.2 and 20.1 in plum and apricot kernel oils. Dhar and Chauhan (1963) found acid values of 9.5 and 1.07 in peaches and apricot; Dang *et al.* (1964) detected as high as 27.14 and 20.10 acid values respectively in *Morpankha* and *Chawaru* cultivars of apricot grown in Kumaon region. However, Abd El-Aal *et al.* (1986) could find only 0.12 acid values in apricot. Wild apricot on the other hand showed the presence in its kernel oil of 3.6 acid values (Aggarwal *et al.*, 1974). In almond and walnut kernel oils the acid value have been recorded as 0.5 – 3.5 and 2.5 respectively (Meyer, 1987). However, according to Indian Food Laws, the acid value in almond oil shall not exceed 6.0 (Anon., 1996).

2.2.7 Peroxide value

When lipids contain unsaturated fatty acids, oxidation takes places at the unsaturated linkages. The process of oxidative degradation of oil gives rise to volatile aldehydes, which imparts a characteristic rancid odour. A measure of oxidative rancidity is the peroxide number, which is expressed as milli-equivalents of peroxide per Kg of lipids. Therefore, peroxides are the main initial products of auto-oxidation and can be measured by various methods based on their ability to liberate iodine from potassium iodide or to oxidize ferrous to ferric ions. Although, peroxide values are applicable to peroxide formation at the early stages of oxidation, it is nevertheless, highly empirical as it varies with procedure of estimation and changes in temperature. During the course of oxidation, peroxide value reaches the peak and then declines (Anon., 1980). In apricot kernel oil the peroxide value has been found to be only 0.12 (Abd El-Aal *et al.*, 1986). Various unsuccessful attempts have been made to correlate peroxide value with the development of rancid flavour. However, mainly owing to the reason that the amount of oxygen that must be absorbed or peroxides that must be formed to produce rancidity vary with the composition of the oil (the more saturated fats need less oxygen absorption to become rancid), the presence of anti-oxidants and trace metals and conditions of oxidation (Nawar, 1985).

2.2.8 Hydro-cyanic acid (HCN)

Cyanogenetic glucosides yielding hydro cyanic acid upon hydrolysis are widely distributed within approximately 150 plant species. Amygdalin (Benzaldehyde cyanohydrin glucoside), probably the first known of this complex glucoside is present in the kernels of stone fruits and was first isolated from the seeds of bitter almond (Liener, 1966). The lethal dose of HCN for human is estimated to be 0.5 – 3.5 mg per kg body weight and occasionally sufficient quantities of cyanogenetic foods are consumed to cause fatal poisoning in humans. Although, accidental cyanide poisoning from consumption of stone fruit kernels is not frequently reported, actual poisoning especially of children is a worldwide occurrence (Sayre and Kaymakcalan, 1964). Apparently many people like the taste of raw kernels. In addition, apricots, peach and cherry kernels have been utilized extensively in Germany and United States for the manufacture of fixed oils, bitter almond oils and macroon paste (Cruess, 1958). Thus, the possibility of the chronic toxicity resulting from regular consumption of low levels has been suggested but not yet proved (Wogan and Marletta, 1985). In different fruit kernels, varying levels of amygdalin and hydro-cyanic acid has been recorded. According to Winton and Winton (1950) an HCN content of 0.06 per cent was recorded in plum kernels. In apricots, the HCN content was also found to be 0.06 per cent (Anon., 1976). However, Aggarwal *et al.* (1974) reported an amygdalin content of 4.3 per cent in wild apricot kernels. Stosic *et al.* (1987) conducted toxicological tests on mice and found that peach, plum and apricot contains 102.66 mg %, 75.65 mg % and 8.10 mg% HCN respectively as the toxic component. Earlier Holzbecker *et al.* (1984) reported that apricot and peach seeds respectively contain 2.92 mg per gram and 2.60 mg per gram HCN in their kernels. Similarly, Stoewsand *et al.* (1975) have shown the presence of 11.7, 177.1, 143.5, 164.0 and 132.5 mg HCN per 100 gram of kernels in *Moorpark, Summerland 4E-55-9, Veecot, Viceroy and Vineland 51175* cultivars of apricot respectively. However, *Amar* cultivar of apricot did not show presence of any HCN in its kernels (Abd El-Aal *et al.*, 1986). Thus, the extent of presence of HCN also varies with the type of fruit, variety and method of extraction of oil.

2.3 DECORTICATION (CRUSHING) OF STONES/PITS

Decortication is the method of breaking the stones/pits of stone fruits or nuts of nut fruits to separate the kernels. It can be performed either manually or by using a mechanical device called decorticator. Reddy *et al.* (1995) in Oil Technological Research Institute, Anantpur developed a hand-operated decorticator for apricot nuts. However, the possibility of using the decorticator in breaking of hardy stones like peach, plum, cherry etc. is yet to be explored and information on this aspect is lacking in the literature.

2.4 KERNEL SEPARATION

The separation of kernels from the crushed mass of stone fruits is quite laborious and time consuming work especially in peaches where the percentage of kernels is very less as compared to the stones/pits of other fruits viz., apricot, peach, plum, prunes etc. Schab and Yannai (1973) separated apricot kernels from crushed mass using a salt solution of specific gravity 1.115. Further no systematic work for separation of kernels from decorticated/crushed mass has been done and information in this aspect is lacking in the literature.

2.5 OIL EXTRACTION

The oil from the oil seeds and fruit kernels is extracted either by solvent extraction or by using oil press or oil expeller. The per cent oil yield is more in solvent extraction method but the cost incurred is also much more. The oil yield by the solvent extraction method was found to be 50.90 per cent in *Amar* variety of apricot (Abd El-Aal, 1986); but the oil expressed by the means of oil press was found to be only 40.42 per cent in wild apricot kernel oil (Aggarwal *et al.*, 1974). In kernels of plums and peaches the oil yield has been reported to vary between 39 – 42 per cent in plums (Anon., 1976) and 32 to 45 per cent in peaches (Winton and Winton, 1950). However, not much information is available on the development of commercial method of oil extraction from stone fruit kernels.

2.6 DETOXIFICATION (Removal of HCN from kernels and oils)

Amygdalin is a natural substance found in variety of plants. Common sources of amygdalin include seeds of apple and pear as well as the leaves, fruits and seeds of black cherry, almond, plum, peach and apricot (Holzbecker *et al.*, 1984). It is a cause of concern, because once amygdalin is ingested it is metabolised to deadly poison HCN through a two-step process. First, amygdalin is metabolised to two molecules of glucose and one molecule of mandelonitrile in the presence of enzyme β-glucosidase. Then, mandelonitrile is converted to HCN and benzaldehyde by the enzyme hydroxynitrile lyase. Both reactions require one molecule of water (Cheeke, 1998). The amygdalin, which releases HCN, considered to be a poison, was used as an anticancer agent in Russia as early as 1845, with positive results reported for the first patient treated (Moss, 1996). Its first recoded use in USA as a treatment for cancer occurred in the early 1920s. At that time, amygdalin was taken in pill form. However, the formulation was judged too toxic, and the work was abandoned (Curt, 1990). Amygdalin also known as vitamin B-17 or laetrile has been tested on cultured animal cells, in whole animals, in xenograft models and in humans to determine whether it has specific anticancer properties, and cyanide is believed to be the main cancer-killing ingredient in laetrile (Newmark *et al.*, 1981 and Rauws *et al.*, 1982). But once HCN is absorbed into the blood stream from the gastro-intestinal tract, cyanide preferentially binds to the protein portion of cytochrome oxidase a- a_3. Cytochrome oxidase a- a_3 is the final enzyme of electron transport chain located in the mitochondria. When cyanide binds to cytochrome oxidase a- a_3, the electron transfer to molecular oxygen is inhibited, thereby halting ATP (energy) generation. Because electrons are unable to be transferred to molecular oxygen, there is a decreased utilization of oxygen and the pressure of oxygen gas increases in the blood. Consequently, the respiration rate is decreased (Salkowski and Penney, 1994). Thus one of the major symptoms of cyanide poisoning is laboured breathing. Other symptom includes salivation, anxiety, headache, ataxia, vertigo, giddiness, lower jaw stiffness and nausea, followed by convulsions, paralysis, coma, cardiac arrhythmia and respiratory failure (Casarett and Doull, 1991). Long-term effects of cyanide include neurological deterioration due to demyelenating lesions of the brain and parkinsonian – like syndrome characterized by rigidity and loss of voluntary muscle action (Murray *et al.*,1988,). Thus, there is a need to remove the HCN content from the kernels prior to their use in extraction of oil and for other purposes. According to Schab and Yannai (1973), the apricot kernels when dipped in water for 150 minutes at pH of 6.5 at 55°C temperature removed 99.3 per cent amygdalin. Bitter almonds used for oil extraction if soaked in salt solution before pressing the oil cake contain undeterminable traces of HCN (Rothea, 1945). A sulphur-containing compound such as sodium thiosulphate is often used as a part of antidotal treatment to ensure that there is ample sulphur available to detoxify all of cyanide (Salkowski and Penney 1994) and remaining cyanide may also be detoxified by infusing hydroxocobalamin (Rindone and Sloane (*et al.*) 1992). However, there is no report available in the literature regarding removal of HCN for the kernels of stone fruits prior to their use in oil extraction purposes.

2.7 STORAGE OF OILS

As such no particular work has been done on storage of peach, plum and apricot oils. These oils mostly comprise of monoenoic and dienoic fatty acids and are likely to change in quality during storage. One of the major causes of spoilage during the storage of oils is oxidation. It is of great economic concern to the food industry because it leads to the development, of various off flavours and off odours generally called rancidity, which reduces their shelf life (Nawar, 1985). According to Chan and Levett (1977), the dienoic (linoleate group) fatty acids are much more susceptible (by a factor of about 20) to oxidation than monoenoic fatty acids (oleate group). The oxidation is however, not a simple oxidation of the double bond. The course of oxidation is now believed to be a chain reaction and the current theories suggest that free radicals are the intermediates. It is suggested that the initiating reaction, under the influence of the light, is the formation of a double free radical as oxygen adds to the double bond, one on the methylenic carbon and one on the oxygen. The free radical may react with the methylenic carbon adjacent to a double bond to form another free radical. Because each of two free radicals formed, is a resonance hybrid receiving contributions from two structures, there are four places at which an oxygen molecule can add to the free radical. The free radical peroxide may react with another methylenic carbon to form a hydroperoxide and another free radical and so a chain reaction starts (Meyer, 1987). The peroxide formed are relatively unstable and enter into numerous and complex breakdown and interaction mechanism responsible for the production of myriad compounds of various molecular weights, flavour thresholds and biological significance (Nawar, 1985). As described by Labuza (1971) the rates of oxidation for arachidonic acid, lionlenic acid, linoleic acid and oleic acid are 40:20:10:1. Fatty acids oxidize at a slightly greater rate when free than when esterified to glycerol. In commercial oils, however, the presence of relatively large amounts of free acids can increase incorporation of catalytic trace metals from equipments of storage tanks and thereby increase the rate of lipid oxidation (Nawar, 1985).

From the above review of literature, it appears that systematic studies on evaluation of stone fruit kernels for oil extraction, development of mechanical decortication for crushing of stones/pits, kernel separation, method for detoxification, oil extraction and its storage is scanty. The present investigations were therefore, carried out to conduct a detailed study on evaluating the suitability of kernels of various stone fruits otherwise a waste, for extraction of oil for various purposes.

MATERIALS & METHODS

3

MATERIALS AND METHODS

The present investigations entitled "Extraction and evaluation of stone fruit kernel oils" were conducted in the department of Postharvest Technology, Dr Y. S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during the year 2000-2002. The experimental details and techniques employed in these studies are described as follows under suitable captions.

3.1 RAW MATERIAL

For conducting preliminary studies on oil extraction and their evaluation for various physico-chemical characteristics, the stones of different cultivars of apricot, peach and plum fruits collected from various locations in Himachal Pradesh (Table3.1) were utilized for further processing.

Table 3.1 Sources of Raw material

Fruit	Variety	Source (amsl)
Apricot	*Chulli* (Wild Apricot)	Kalpa, Distt. Kinnaur (2500 m)
		Parwanoo, Distt Solan (500 m)
	New Castle	Rajgarh, Distt Sirmour (950 m)
Peach	*Elberta*	Rajgarh, Distt Sirmour (950 m)
	July Elberta	Rajgarh, Distt Sirmour (950 m)
Plum	*Santa Rosa*	Shamshi, Distt Kullu (1200 m)
		Nauni, Distt. Solan (1276 m)
		Jarol, Distt Mandi (800 m)
	Methley	Kwag Dhar, Distt Shimla (2550 m)
	Kanto-5	Nauni, Distt Solan (1276 m)
	Red Ace	Nauni, Distt Solan (1276 m)
	Golden Drop	Nauni, Distt Solan (1276 m)
	Prunes	Manikaran, Distt Kullu (1350 m)

The kernels were separated by breaking the stones manually in between two iron blocks / stones and were utilized for oil extraction using Soxhlet oil extraction apparatus (Ranganna, 1997). The crude fat so extracted was analyzed for various physico-chemical characteristics.

3.2 STANDARDIZATION OF METHOD FOR DECORTICATION OF STONES/PITS

For optimizing the method for crushing the stones (decortication), the pits of different fruits were collected from various fruit processing units in Himachal Pradesh viz. peach stones from Government Fruit Canning Unit Rajgarh (Distt Sirmour), plum stones from hpmc Fruit Processing Plant, Jarol (Distt. Mandi) and apricot stones from hpmc Fruit Processing Plant, Parwanoo (Distt Solan). These stones are otherwise thrown away as waste in the fruit processing plants. The stones/pits as received from the processing units were spread on the open floor/open sun to remove the adhering moisture prior to its use for decortication.

3.2.1 Manual decortication

Manual crushing (decortication) of stones/pits of peach, plum and apricot was performed by placing them in a thick cloth/thin gunny bag and breaking the same with the help of an iron block.

3.2.2 Mechanical decortication

Mechanically, the stones of peach, plum and apricot were decorticated by using a mechanical decorticator, specially got designed and fabricated from the Division of Agricultural Engineering, Indian Agricultural Research Institute, New Delhi. Decorticator is a type of roller crusher, which consists of two rollers moving in opposite directions with the help of 3 HP motor and is provided with a hopper and a feeder assembly. The clearance (distance) between the two rollers meant for crushing of stones was adjusted according to the respective size of stones/pits (Plate 1). Triplicate determinations were made for each method of decortication. The suitability of mechanical decorticator was optimized on the basis of highest percentage of

Plate 1. STONE FRUIT PITS

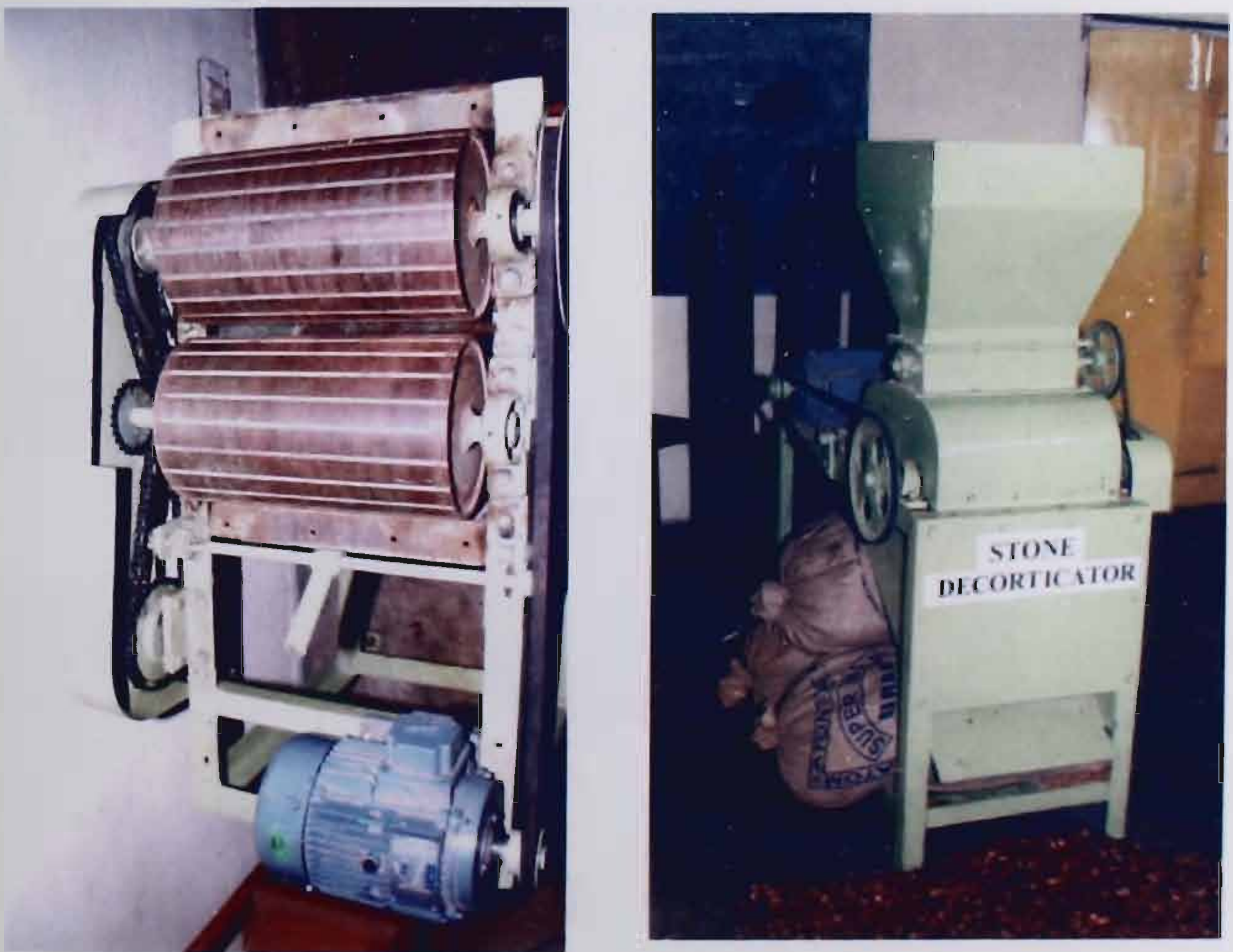

Plate 2. STONE DECORTICATOR

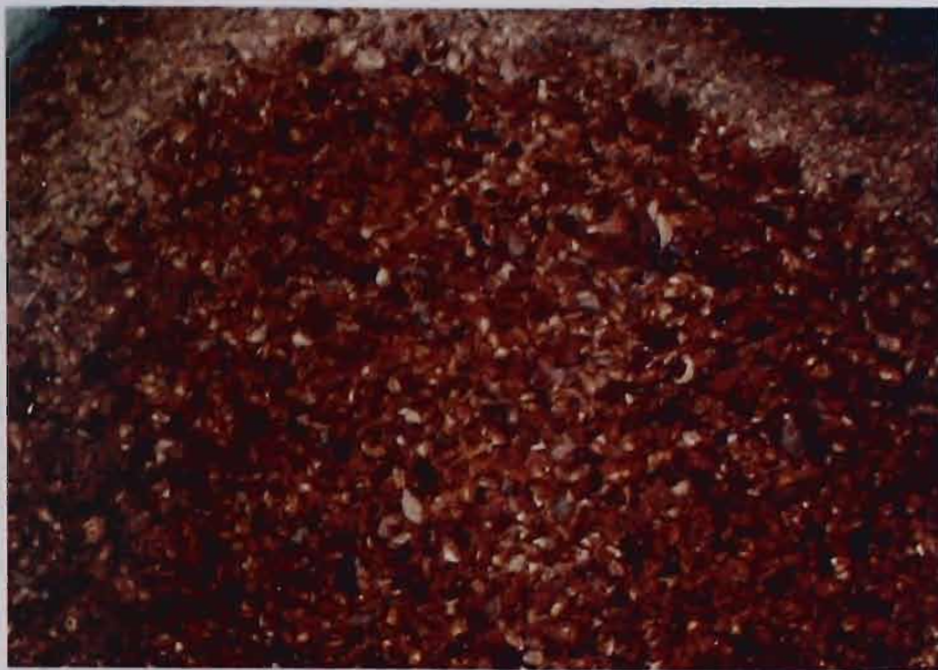

Plate 3. DECORTICATED MASS OF STONE FRUITS

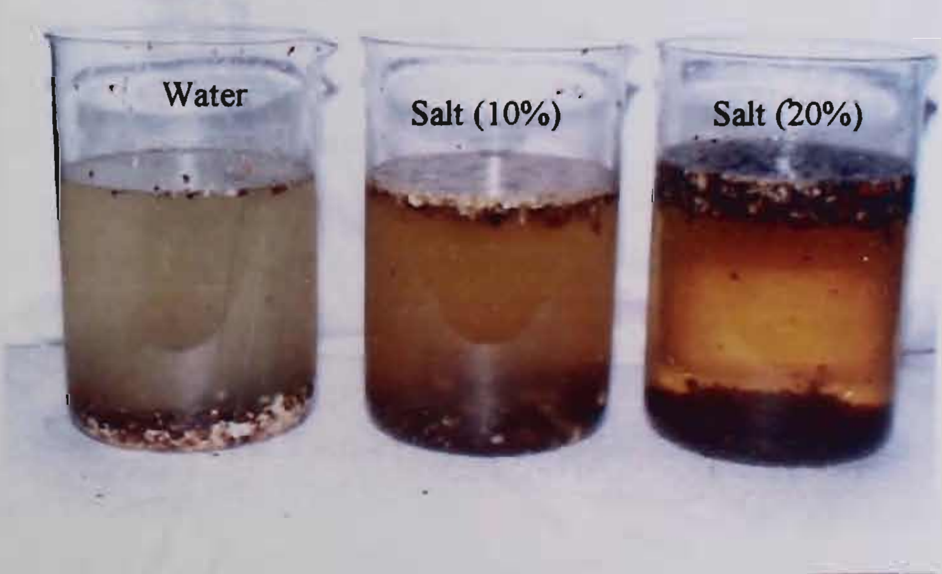

Plate 4. SPECIFIC GRAVITY SEPARATION

decortication and the recovery of maximum quantity of decorticated(crushed) stones within a given time interval.

3.3 STANDARDIZATION OF METHOD FOR KERNEL SEPARATION

The crushing of stones/pits by using either manual or mechanical method of decortication results in a mixture of kernels, broken shells, excessively crushed/pressed kernel/shells and uncrushed stones. Therefore, the kernels are required to be separated from the mixture prior to their use for extraction of oil. Following methods have been evaluated for separation of kernels from the crushed mass of stones/pits.

3.3.1 Manual separation

The stone fruit kernels were separated manually from a mixture of kernels and broken shells, crushed and unbroken stones obtained after both the methods of decortication.

3.3.2 Kernel Separation by floatation in water

The suitability of using floatation in water method for separation of kernels was evaluated. In this method the decorticated/crushed mass of stones/kernels was dipped in sufficient quantity of tap water to separate the kernels presuming that they may float on water while shells settle at the bottom due to difference in the density of the shells and the kernels.

3.3.3 Specific gravity separation

For standardizing the method for the separation of kernels, salt solution of different specific gravities were prepared by using varying concentrations of salt in water such as 5, 10,15 and 20per cent. The mixture of kernels and broken shells in the crushed mass was dipped in the solutions and the kernels were allowed to float on the top while shells settle at the bottom. The kernels floating on the top of salt solution were separated by using sieves or muslin cloth. The kernels after separation were then allowed to dry either in open sun or in mechanical dehydrator (2 hours) prior to their use for oil extraction. The method involving maximum kernel separation per unit time (hours) with ease of handling was optimised and used for further experimentation.

3.4 KERNEL OIL EXTRACTION

The kernels of peach, plum and apricot stones were utilized for the extraction of oil by using following methods. The suitability of the method was evaluated by comparing the various attributes of extracted oil viz., quality characteristics, ease of handling and cost of production of oil.

3.4.1 Solvent extraction

The stone fruit kernels after drying and crushing were placed in the Soxhlet apparatus for extraction of oil using petroleum ether (40-60°C) as a solvent (Ranganna, 1997). After 16-18 hrs of extraction process the crude oil/fat was collected by evaporating the solvent. The extracted oil was packed in glass vials for its further use in analytical purposes.

3.4.2 Oil press (portable power ghani)

The suitability of using oil press (portable power ghani) commonly used for sarson/toria/lentil oil extraction was evaluated for expression of oil from stone fruit kernels. In contrast to commercial kohlu, the contact parts of this power ghani (M/s Kisan Krishi Yantra Udyog, Kanpur, India) within the crushing/pressing zone were made of wood (Plate 6). During crushing and pressing of kernels in the power ghani a little quantity of hot water is also sprinkled over the crushed mass of kernels to help in better releasing of oil. The expressed oil is then filtered through muslin cloth and centrifuged prior to packing in glass bottles for later use.

Plate 5. SEPARATED KERNELS OF STONE FRUIT PITS

(a) (b)

Plate 6. OIL PRESS: (a) CONTACT PARTS MADE OF SS
(b) CONTACT PARTS MADE OF WOOD

3.5 REMOVAL (DETOXIFICATION) OF HYDRO CYANIC ACID (HCN) FROM THE FRUIT KERNELS

The stone fruit kernels are known to contain various bittering and toxic principles, which are required to be removed or inactivated prior to their use for oil extraction purposes. Following methods have been evaluated for their efficacy to detoxify the kernels (Table 3.2)

Table 3.2 Details of different methods of removal of hydro cyanic acid (detoxification) from stone fruit kernels.

Method for detoxification	Details/ Remarks
1. Immersion in water	The stone fruit kernels after crushing were dipped in water for various time intervals to remove hydro--cyanic acid (HCN)
2. Immersion in salt solution	The kernels after crushing were immersed in salt solution (20%) for different time intervals.
3. Dipping in a solution of β-glucosidase	The crushed kernels were dipped in a solution of β-glucosidase to hydrolyse and break amygdalin into glucose, benzaldehyde and HCN which is then released in to water
4. Immersion in a solution of sodium thiosulphate	The crushed mass of kernels was dipped in different concentrations of sodium thiosulphate which react with HCN to form a non-harmful salt

3.6 STORAGE STUDIES

Stone fruit kernel oil extracted by using portable power ghani after decortication and kernel separation (Fig. 1) was packed in two different packages (transparent and coloured glass bottles) and stored at ambient temperatures (10.2°C – 25.3°C) for a period of six months to evaluate its storage stability(Fig.1). The observations regarding changes in various quality characteristics were recorded at periodic intervals of 0,2,4 and 6 months. The quality attributes of kernel oils from various fruits were also compared with the quality standards of almond oil as specified in the Prevention of Food Adulteration Act and Rules (Anon., 1996).

3.7 PHYSICAL CHARACTERISTICS OF STONES

Ten stones each of different cultivars of peach, plum and apricot at random were selected for determining the physical characteristics.

3.7.1 Size of stones/pits, kernels and shells

Size parameters comprising of length, breadth and thickness of stones and kernels and thickness of shells were recorded with a help of Vernier Calliper and expressed in millimetre (mm).

3.7.2 Average weight

Average weight (g) of stones/pits as well as kernels were determined gravimetrically.

3.7.3 Specific gravity of stones and kernels

Specific gravity of stones and kernels was determined according to the method as detailed by Ting and Rouseff, (1981).

3.8 PHYSICO-CHEMICAL CHARACTERISTIC OF OILS

3.8.1 Colour

The colour of oil was measured in a Lovibond Colour Tintometer and expressed as Tintometer unit of Yellow (Y), Red (R) and Blue (B).

SCHEMATIC DIAGRAM FOR EXTRACTION OF KERNEL OILS

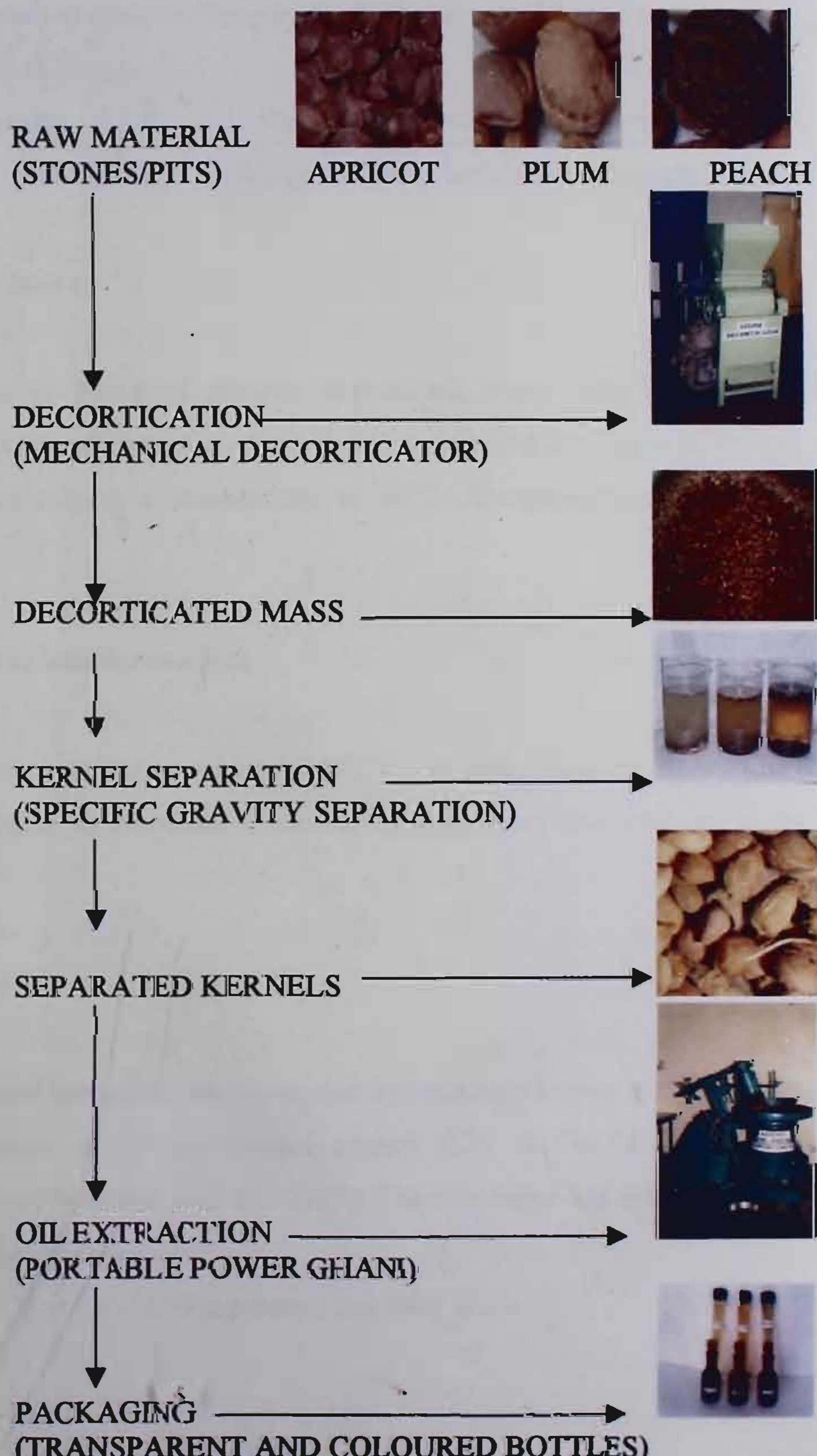

Fig 1. Flow sheet for extraction of oils from apricot, plum and peach kernels

3.8.2 Specific gravity

The specific gravity of oil was measured using specific gravity bottles, according to the standard method (Ranganna, 1997) and calculated as under.

$$\text{Specific Gravity} = \frac{\text{Weight of oil with bottle} - \text{Weight of bottle}}{\text{Weight of water with bottle} - \text{Weight of bottle}}$$

3.8.3 Refractive index

The refractive index of oil was determined using Abbe's refractometer (Model Advance Research Inst. Co., New Delhi) by placing 2-3 drops of sample on the prism and maintaining a temperature of 40°C throughout the measurements (AOAC, 1995).

3.8.4 Butyrorefractometer reading

The butyrorefractometer reading (40°C) was calculated by converting the refractive index value to butyrorefractometer reading from the table as given in AOAC (1995).

3.8.5 Acid Value

Acid value of kernel oils was estimated by titrating a known weight of sample (7.05g) with addition of 50 ml alcohol against 0.25 N NaOH solution using phenolphthalein as an indicator (AOAC, 1995). The titre value has been expressed as per cent free fatty acid as oleic acid.

$$\text{Acid Value} = 1.99 \times \text{per cent free fatty acids}$$

3.8.6 Peroxide value

Peroxide value was estimated by taking the sample (5.00 g) mixed with Acetic Acid- Chloroform solution and saturated KI solution and titrating against 0.1 N sodium thiosulphate using starch as an indicator and calculated as milli-equivalent peroxide/kg sample (AOAC, 1995).

$$\text{Peroxide Value} = \frac{(\text{Sample titre} - \text{blank titre}) \times \text{Normality of } Na_2S_2O_3 \times 1000}{\text{Weight of sample taken in grams}}$$

3.8.7 Saponification number

Saponification number of different kernel oils was estimated according to the standard method (AOAC, 1995). In this method the sample mixed with alcoholic potassium hydroxide is refluxed for thirty minutes to completely saponify the sample and then titrated against 0.5 N HCl using phenolphthalein as an indicator. Blank determination is also made along with the sample

$$\text{Saponification number} = \frac{28.05\ (\text{Blank titre} - \text{Sample titre})}{\text{Weight of sample taken in grams}}$$

3.8.8 Iodine value

Iodine value was estimated according to Wijs (Cyclohexane-Acetic acid solvent) method (AOAC, 1995). In this method, the sample (0.26 – 0.32g) is mixed with Cyclohexane- Acetic acid solvent followed by addition of Wijs solution and then stored in dark for one hour followed by titration against 0.1 N Sodium thiosulphate using starch solution as an indicator. After subtracting the sample titre from the blank titre iodine value was calculated as under:-

$$\text{Iodine value} = \frac{(\text{Blank titre} - \text{Sample titre}) \times \text{Normality of } Na_2S_2O_3 \times 12.69}{\text{Weight of sample in grams}}$$

3.8.9 Thiocyanogen value

Thiocyanogen value of kernel oil was determined according to the method as reported by Ranganna (1997). In its estimation the sample of kernel oil was mixed with thiocyanogen solution and stored in dark followed by titration against 0.1 N

Sodium thiosulphate using starch solution as an indicator. Thiocyanogen value was then calculated using the following calculations.

$$\text{Thiocyanogen value} = \frac{(\text{Blank titre} - \text{Sample titre}) \times \text{Normality of } Na_2S_2O_3 \times 12.69}{\text{Weight of sample in grams}}$$

3.8.10 Fatty acid composition

The fatty acid composition was calculated by the equations given by Ranganna (1997) where thiocyanogen value and iodine value are equated to give approximate composition of oleic and linoleic acid and is expressed in percentage.

3.8.11 Hydro-cyanic acid (HCN)

HCN was estimated by titrating the sample against 0.1 N silver nitrate using potassium chromate as an indicator (AOAC, 1995) and the amount of hydro-cyanic acid (HCN) present in kernel and oil was calculated as under.

$$1 \text{ ml } 0.1 \text{ N } AgNO_3 = 0.0027 \text{ g HCN}$$

3.9 STATISTICAL ANALYSIS

The data on physico-chemical characteristics of stone fruits kernels and oils before and during storage were analysed statistically by following Completely Randomised Design (Cochran and Cox, 1967), Arc Sign Transformation and Logarithmic Sign Transformation (Gomez and Gomez, 1984).

3.10 COST OF PRODUCTION

Cost of production of decortication, kernel separation and oil extraction was calculated taking into consideration various input costs such as cost of raw material, labour, electricity, processing cost, packaging and other charges. The sale price of the product was calculated after adding 20% profit margin as the total sale price of each oil.

RESULTS & DISCUSSION

4

RESULTS AND DISCUSSIONS

The present investigation entitled "Extraction and evaluation of stone fruit kernel oils" was conducted in the Department of Post harvest Technology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.) during the year 2000-2002. The results of this study presented in Tables 4.1-4.18 have been discussed as under:-

4.1 PHYSICO-CHEMICAL CHARACTERISTICS: Fruits, Stones and Kernels

Physical characteristics of three stone fruits under study indicate that only 89.90-96.76% is the edible portion and substantial percentage (3.24-10.10%) comprises of stones/pits, which are otherwise thrown away as waste. The pulp/stone ratio in different fruits has been found as 9.9:1 – 13.3:1 (apricot); 15.94:1 – 30.77:1 (plum); 20.42:1 – 21.43:1 (peach). Thus, there exists an ample scope for successful utilization of stones/pits for oil extraction purposes. The data pertaining to physical characteristics of stones/pits (Table 4.1) of different fruits indicate that length (horizontal diameter) of the apricot stones ranged between 16.53 mm (*Chulli*) to 19.57 mm (*New Castle*) against a value of 16.71 to 28.09 mm found in case of plum stones. The peach stones however, were larger in size with length parameter varying between 35.22 mm (*July Elberta*) to 39.41 mm (*Elberta*). The breadth (vertical diameter) of stone in three stone fruits ranged between 13.17 mm to 24.74 mm with maximum width in case of peach (cv. *July Elberta*) and minimum in case of plums (cv. *Methley*). Similarly, the thickness of stones was found maximum in *July Elberta* peach (17.67 mm) and minimum in stones of plum cv. *Methley* (7.37 mm). However, size parameter of apricot recorded by Sharma (2000) was slightly larger than the size of the apricot used in the study. Thus the peach stones were largest in size followed by stones of plums and apricots.

Table 4.1: Physico-chemical characteristics of apricot, peach and plum stones and kernels

Parameters	Apricot		Peach		Plum						$CD_{0.05}$
	Chulli	New Castle	Elberta	July Elberta	Santa Rosa	Methley	Kanto-5	Red Ace	Golden Drop	Prune	
Pulp/stone ratio	9.9	13.3	20.42	21.43	30.77	15.94	22.97	27.03	21.89	18.34	-
Size of stones:											
(i) Length (mm)	16.53	19.57	39.41	35.22	19.46	16.71	19.26	18.92	19.20	28.09	0.55
(ii) Breadth (mm)	14.29	17.64	24.74	24.00	13.51	13.17	13.52	14.09	14.61	14.38	0.35
(iii) Thickness (mm)	10.10	10.46	17.13	17.67	7.94	7.64	7.37	9.01	8.75	9.28	0.28
Weight of stones (g)	1.16	1.50	5.94	4.95	0.75	0.56	0.82	0.82	0.84	1.73	0.06
Specific gravity of stones	0.91	0.88	0.96	0.94	0.84	0.96	0.93	0.99	0.94	0.90	0.03
Thickness of shell (mm)	1.19	2.01	5.64	4.84	1.72	1.37	1.13	1.11	1.52	2.03	0.07
Size of kernels:											
(i) Length (mm)	12.55	13.88	18.31	17.76	11.61	11.46	14.20	12.45	12.29	16.61	2.73
(ii) Breadth (mm)	8.85	9.77	11.53	10.75	5.70	5.58	7.65	8.07	8.26	7.54	0.33
(iii) Thickness (mm)	6.42	5.27	2.74	2.86	3.13	2.83	3.83	4.24	3.76	4.31	0.28
Weight of kernels (g)	0.35	0.42	0.35	0.28	0.07	0.08	0.13	0.17	0.14	0.26	0.02
Specific gravity of kernels	1.123	1.119	1.127	1.128	1.118	1.117	1.116	1.120	1.143	1.123	0.002
Kernel recovery (%)	30.16	28.00	5.87	5.67	9.33	14.24	15.87	20.75	9.07	12.77	1.66
Oil recovery (%)	43.03	44.36	44.71	51.08	43.63	40.25	41.75	41.37	40.72	39.73	1.22
Stone/ kernel ratio	3.31	3.57	17.00	17.71	10.96	7.03	6.33	4.82	6.11	6.69	-
Presence of HCN	+	+	+	+	+	+	+	+	+	+	-

removal (detoxification) and for use in various pharmaceutical purposes needs to be studied in detail. The kernels of all the stone fruits showed the presence of HCN (Table 4.1and Plate- 11)

According to FAO production figures, the total quantity of stone fruits available in our country is 9,400 MT apricot, 1,14, 000MT peach and 7,4000 MT plums (FAO, 2001), out of which Himachal Pradesh alone produces about 243, 367 and 10,574 MT of apricot, peach and plums respectively (Anon., 2000). Apart from table uses, the edible portion is mainly utilized for canning and other processing purposes, and stone is as such thrown as waste. Thus on the basis of composition, the availability of stones/pits from apricot, peach and plum is expected to be 808.4, 5472.0 and 3256.0 MT in India and 20.9, 17.64 and 465.3 MT in Himachal Pradesh alone (Table-4.2). Out of these stones, the kernel recovery for stone fruits shall be 998.7 MT (apricot, peach and plum) in India and 70.8 MT (apricot, peach and plum) in Himachal Pradesh. From these kernels, the oil yield is expected to be 438.6 MT in India and 29.4 MT in Himachal Pradesh. The potential cultivars of stone fruits, which are used for processing, have been identified as *Chulli* (apricot) *Santa Rosa* (plums) and *Elberta* and *July Elberta* peaches. So the stones/pits of stone fruits which are otherwise thrown away as pits can successfully be utilized for the production of oil for various purposes viz., pharmaceutical, cosmetics and as well as for edible uses.

4.2 PHYSICO-CHEMICAL CHARACTERISTICS OF OIL

The visual appearance of the kernel oil from all the stones was yellowish except the kernel oil from *Santa Rosa* cultivar of plum, which was described as reddish yellow (Table 4.3 and Plate 7, 8, 9, 10).

The specific gravity in different kernel oils ranged between 0.890-0.915, and the difference between various kernel oils, was found to be non-significant. Earlier Saadany *et al.*, (1994) and Rahma and Abd El-Aal, (1988) reported a specific gravity of 0.914 and 0.915 respectively in peach kernel oils. Similarly, the specific gravity of oil from kernels used in the study was also well within the range of specific gravity reported by Eckey (1954) in kernel oil of peach (0.913-0.918), plum (0.911-0.916);

Table 4.2 : Availability of important stone fruits, their pits, kernels and expected kernel oil yield.

Fruits	Production (MT)		Stone (%)	Availability of stone (MT)		Kernel (%)	Availability of kernel (MT)		Oil yield (%)	Expected oil yield (MT)	
	India[1]	H.P.[2]		India	H.P.		India	H.P.		India	H.P.
Apricot	9400	243	8.6	808.4	20.9	29.1	235.2	6.1	43.7	102.8	2.7
Peach	1,14,000	367	4.8	5472.0	17.6	5.8	317.4	1.0	47.9	152.0	0.5
Plum	74,000	10574	4.4	3256.0	465.3	13.7	446.1	63.7	41.2	183.8	26.2
Total	197,400	11,184		9536.4	503.8		998.7	70.8		438.6	29.4

[1]FAO (2001) , [2]Anon (2000)

Plate 7. APRICOT KERNEL OILS

Plate 8. PEACH KERNEL OILS

and apricot (0.912-0.916). Abd El-Aal *et al.*, (1986) reported a specific gravity of 0.9136 in apricot kernel oils, while in wild apricot (*Chulli*) kernel oil it has been found to be 0.917 (Aggarwal *et al.*, 1974). *Morpankha* and *Chawaru* cultivars of apricot of Kumaon region had a slightly higher value of specific gravity (Dang *et al.*, 1964).

Similar to specific gravity, the refractive index in kernel oils of different fruits ranged between 1.46-1.47 and difference in different oils was found to be non-significant. The refractive index of the oils indicates the degree of unsaturation, as such more the refractive index more will be the unsaturation (Nawar, 1985). The refractive index in kernel oils of different fruits has been reported to be 1.469 (25^0C) in peach kernel oil (Saadany *et al.*, 1994 and Rahma and Abd El-Aal, 1988); refractive index of 1.462-1.464, 1.462-1.465 and 1.462-1.465 in peach, plum and apricot kernel oils respectively (Eckey, 1954); 1.471 (18.5^0C) and 1.4718 (20^0C) in kernel oils from *Morpankha* and *Chawaru* cultivars of apricot respectively (Dang *et al.*, 1964); 1.4672-1.4692 in oil of different varieties of apricot of Ladakh region (Kapoor *et al.*, 1987); 1.465 (35^0C) in wild apricot kernel oil (Aggarwal *et al.*, 1974); 1.4635 (40^0C) in apricot oil extracted from processing waste (Iordanidou *et al.*, 1999) and a value of 1.4633 (25^0C) refractive index in cultivar *Amar* grown in Egypt (Abd El-Aal *et al.*, 1986). Thus the values of the refractive index of our kernel oils were well within the range of refractive index recorded by various workers.

Butyrorefractometer reading (40°C) obtained after conversion from refractive index was found to be maximum (69.5) in apricot kernel oil (*Chulli*) and minimum (49.5) in kernel oil from July Elberta cultivar of peach, while in plum kernel oils it ranged between 57.5-66.5. According to PFA (Prevention of Food Adulteration Act), the butyrorefractometer reading in almond oil shall vary within 54-57 (Anon., 1996). Thus, the kernel oils from stone fruits contained slightly higher butyrorefractometer value than that of almond kernel oil.

The acid value denotes the amount of free fatty acids present in the oil and is the indicator of hydrolytic rancidity. Kernel oil from different stone fruits indicate that plum kernel oil had least amount of acid value (0.2-2.07) followed by apricot kernel oil (2.26-4.31) and kernel oil from *Elberta* cultivar of peaches (6.17). The kernel oil from *July Elberta* peaches however, had the highest amount of acid value (25.61). These findings thus suggest that peach kernel oil is more prone to spoilage than the other oils and needs to be packed/stored more carefully. Our figures of acid value in different kernel oils corroborated the findings of other workers viz., 0.5-3.0 in plum oil and 0.2-4.0 in apricot oil (Eckey, 1954); 3.6 in wild apricot kernel oil (Aggarwal *et al.*, 1974). However, Dang *et al.*, (1964) recorded very high figure of acid value i.e. 27.14 and 20.10 in *Morpankha* and *Chawaru* cultivars of apricot of Kumaon region. Similarly, Saadany *et al.*, (1994) obtained an acid value of only 0.19 in peach kernel oil. Thus, wide variation in acid value of different kernel oils is available within the same fruit cultivar.

Peroxide value is the measurement of peroxides initially present in the oil and those formed during storage. In kernel oils of different fruits, the peroxide value ranged between 1.53-5.39 with the minimum peroxide value recorded in kernel oils from *Prunes* followed by *Santa Rosa* plum while *Chulli* (wild apricot) cultivar of apricot showed the presence of highest (5.39) amount of peroxide value. According to Jacobs (1958) the high peroxide value is the indicator of spoilage in unsaturated fatty acids and shall not exceed 125. As the peroxide value in oils is much below the critical limit, thus they are less likely to be spoiled. However, the extent of oxidation also depends upon the presence of inherent antioxidants like tocopherols in the oil.

Iodine value on the other hand is the degree of unsaturation present in the oil. Generally, more the iodine value more is the unsaturation (Thimmaiah, 1999). The iodine value in the kernel oils of different cultivars of stone fruits has been found to vary between 93.0 – 121.8 (plums), 100.2-112.9 (apricot) and 106.3-112.8 (peach). The iodine value of the almond oil specified under Indian Food Laws is reported to range between 96 and 100, thus our kernel oil were well within the range of iodine value specified for almond kernel oil (Anon., 1996). Similar to our findings, the iodine value in the kernel oils of different fruits by various workers was 91.0 (Anon., 1976) and 100-110 in plums (Eckey, 1954); 104.0 (Saadany *et al.*, 1994); 84.2 (Rahma and Abd El-Aal, 1988) and 95-110 (Eckey, 1954) in peach kernel oils; and 97-109 (Eckey, 1954); 85-123 (Kapoor *et al.*, 1977); 103.8 (Abd El-Aal, *et al.*, 1986); 99.54-109.9 (Dang *et al.*, 1964) and 80.8-123.0 (Iordanidou *et al.*, 1999) in kernel oil

Plate 9. PLUM KERNEL OILS

Plate 10. PRUNE KERNEL OIL

from different cultivars of apricot. Aggarwal *et al.*, (1974) also recorded a figure of 104.1 iodine value in wild apricot kernel oils.

Saponification value determines the mean molecular weight of the fatty acid originally bound as triglycerides (Ranganna, 1997). Though, there was not much difference in the saponification value of the kernel oils of different fruits yet it was found to vary between 190.6 to 194.6 in peach, 190.2 to 194.4 in apricot and 187.5 to 193.8 in plum kernel oils. Earlier, Anon., (1976) and Eckey (1954) also reported a figure of 192 and 188-195 in plum kernel oil. Similarly, Eckey (1954), Rahma and Abd El-Aal, (1988) and Saadany *et al.*, (1994) observed the saponification value of 189-194, 192.0 and 186.0 respectively in peach kernel oils. While in apricot kernel oils, the saponification value has been reported to be 188.20 (Eckey, 1954); 189.7 (Abd El-Aal *et al.*, 1986); 188.8 (Aggarwal *et al.*, 1974); 187.3-195.0 (Iordanidou *et al.*, 1999) and 191.3-193.8 (Dang *et al.*, 1964).

Thiocyanogen value is used in relationship with iodine value to calculate the oleic and linoleic acid content in the oils. Thus, the calculated value of the oleic acid in the kernel oils of the different stone fruits ranged between 59.67 and 72.59 with maximum oleic acid found in *New Castle* cultivar of apricot. The linoleic acid content on the other hand, was found to be maximum in kernel oil of *July Elberta* peaches (30.20%) and minimum in *Prunes* (15.27%). Earlier, Sherin *et al.*, (1993) recorded a value of 68.88 % oleic acid and 15.77 % linoleic acid in kernel oil of *NJA-13* apricot cultivar grown in Pakistan. Similarly, Beyer and Melton (1990) also reported the presence of 69% and 26% of oleic and linoleic acid respectively in kernel oil of *Moorpark* cultivar of apricot. According to Kapoor *et al.*, (1987) the oleic and linoleic acid content in different cultivars of apricot grown in Ladakh region ranged between 50.95% to 83.33% and 9.62% to 45.90% respectively. Similarly, kernel oil from *Amar* cultivar of apricot grown in Egypt was reported to contain 66.29 and 28.64% of oleic and linoleic acid respectively (Abd El-Aal *et al.*, 1986). Wild apricot kernel oil also showed the presence of 74.3% and 21.6% of oleic and linoleic acid respectively (Aggarwal *et al.*, 1974). Plums and peach kernel oils however contained 65.2% and 63.8% oleic acid and 19.8% and 15.4% of linoleic acid (Anon., 1976 and Rahma and Abd El-Aal, 1988). Thus, the kernel oils from the stone fruits containing 59.67 to 72.59% oleic acid and 15.27% to 30.20% linoleic acid was regarded as the rich source of mono-unsaturated fatty acids and in composition, all the oils are almost similar in

Table 4.3: Physico-chemical characteristics of oil from apricot, peach and plum kernels

Parameters	Apricot		Peach		Plum						$CD_{0.05}$
	Chulli	New Castle	Elberta	July Elberta	Santa Rosa	Methley	Kanto-5	Red Ace	Golden Drop	Prune	
Colour:											
Yellow	2.3	3.9	2.6	41.0	3.1	13.4	3.4	5.4	3.2	5.3	-
Red	0.0	0.9	0.1	1.1	2.0	0.6	0.5	0.4	1.1	1.1	-
Blue	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.1	0.2	0.3	-
Specific gravity	0.914	0.915	0.910	0.890	0.913	0.911	0.913	0.914	0.914	0.906	0.0015
Refractive index (40°C)	1.472	1.470	1.470	1.459	1.464	1.469	1.465	1.470	1.466	1.468	0.002
Butyrorefractometer reading (40°C)	69.5	66.5	66.5	49.5	57.5	65.0	59.0	66.5	60.5	63.5	-
Acid value	2.26	4.31	6.17	25.61	1.01	1.33	1.49	1.03	2.07	0.27	0.49
Peroxide value	5.39	4.38	5.13	3.49	2.58	4.11	5.05	3.60	2.74	1.53	0.56
Iodine value	100.2	112.9	106.3	112.8	95.8	121.8	105.6	101.5	104.7	93.0	1.39
Saponification value	190.2	194.4	194.6	190.6	191.5	187.5	190.2	189.5	191.3	193.8	1.84
Thiocyanogen value	82.24	83.63	83.03	86.80	77.33	90.23	83.21	80.00	82.60	72.68	3.16
Oleic acid (%)	69.50	72.59	63.61	64.28	63.34	65.80	64.66	62.41	64.47	59.67	0.87
Linoleic acid (%)	20.67	26.30	27.07	30.20	21.11	26.20	21.99	20.06	18.77	15.27	0.67

composition to that of almond kernel oil and can find use in many household edible purposes.

4.3 STANDARDIZATION OF METHOD FOR DECORTICATION

Breaking of stones/pits of peach, plum and apricots followed by separation of kernels is the most time-consuming and difficult unit operation. Therefore, for simplifying the whole operation, a mechanical decorticator was got fabricated from the Prototype Manufacturing Unit of Division of Agricultural Engineering in Indian Agricultural Research Institute, New Delhi (India) by keeping in view the various size parameters of the pits of different stone fruits. The efficiency of the mechanical decorticator was compared with that of manual breaking of stones (yield of decorticated stones per hour). Data in Table-4.4 reveal that only 2.25 to 6.03 Kg of stones could be broken manually within one hour as against 42.00 to 94.67 Kg decortication obtained by using mechanical decorticator within the given time interval. Further it was also observed that kernels were not crushed with the mechanical decortication while by using manual crushing, sometimes kernels also got crushed, thus making the separation most difficult. The variation in decortication within stones of different fruits was due to the variation in size and hardness of the stones. Peach stones being larger in size yielded more quantity of crushed mass followed by the stones of plum and apricot. On the basis of average variation in size of stone (length, breadth and thickness) the clearance (distance) between the two rollers for stones of different fruits has been optimised as 8.68mm for apricot; 6.93mm for plum and 12.69mm for peach (Plate 2). The per cent decortication using manual and mechanical means of breaking stones was determined by measuring weight of decorticated mass from the initial weight of stones used for decortication within a given period of time. Manual breaking of stones yielded 92.3, 94.67 and 97.33 per cent of crushed stones of plum, apricot and peach which indicate that even by using manual breaking some stones still remain unbroken/uncrushed. The mechanical decortication however, resulted in breaking of 71.0, 76.33 and 85.0 per cent of decorticated mass of peach, plum and apricot stones (Table-4.4). The stones which remained uncrushed / undecorticated were either very small in size or they

Table 4.4: Standardization of method for decortication of apricot, peach and plum stones/pits

Fruit pits/stones	Decorticated stones (yield Kg/hr)		Mean	(%)Decortication		Mean
	Manual Decortication	Mechanical Decortication		Manual Decortication	Mechanical Decortication	
Apricot	2.25	42.00	22.13	94.67	85.00	89.84
Peach	6.03	94.67	50.35	97.33	71.00	84.17
Plum	3.77	63.00	33.39	92.33	76.33	84.33
Mean	4.02	66.56		94.78	77.44	

$CD_{0.05}$

Fruit (T)	:	3.99	3.92
Method (M)	:	3.26	3.20
T x M	:	5.65	5.55

Table 4.5: Cost of decortication (crushing) of stones/pits of apricot, peach and plum

Particulars	Quantity		Rate	Cost of Decortication					
	Manual decortication	Mechanical decortication		Manual decortication			Mechanical decortication		
				Apricot	Peach	Plum	Apricot	Peach	Plum
Electricity charges/hr	-	2.2 units	Rs.0.65 /unit	-	-	-	1.43	1.43	1.43
Manual labour /hr	1	2	Rs.55 /8hrs.	6.88	6.88	6.88	13.76	13.76	13.76
Depreciation on machinery/hr	-	1 hr.	10%/year	-	-	-	1.03	1.03	1.03
Total cost per hour	-	-	-	6.88	6.88	6.88	16.22	16.22	16.22
Quantity of stones decorticated (Kg/hr)	-	-	-	2.25	6.03	3.77	42.00	94.67	63.00
Unit cost of stone decortication (Rs./Kg)	-	-	-	3.06	1.14	1.83	0.39	0.17	0.26

passed through the sidewalls of the roller. These findings thus suggest the need of grading of stones prior to their decortication and some modification in the adjustment of the rollers. The cost of breaking of stones has been calculated for manual as well as mechanical method of decortication. The manual breaking of stones involved an expenditure of Rs. 1.14 to Rs. 3.06 for each Kg of stone/pit while mechanical decortication took only Rs. 0.17 to Rs. 0.39 for breaking/crushing each Kg of stones/pits of apricot, peach and plum (Table-4.5). Thus, keeping in view the ease of handling, cost of decortication and better yield of crushed mass per unit time, the mechanical decortication of stones has been optimised and recommended for further use in oil extraction purposes. As expected the manual breaking of stones was too laborious, costly and time-consuming affair.

4.4 STANDARDIZATION OF METHOD FOR KERNEL SEPARATION

From the crushed mass of stones/pits (Plate 3), the kernels are separated manually, which is most time consuming and laborious unit operation. In order to improve the efficiency of operation, different methods of kernel separation were attempted viz., floatation in water, specific gravity separation and manual separation. Data in Table-4.7 reveal that dipping crushed mass in 20% salt solution (1.158 specific gravity) brought about complete separation of kernels which floated on the top of salt solution due to difference in density of kernels while shells settled at the bottom (Plate 4, 5). In apricot, plum and peach kernels the separation ranged between 99.98 to 100%. Using salt solution of lower concentration 5, 10 and 15% did not yield optimum separation of kernels. Similarly, dipping crushed mass in simple tap water (floatation in water) was found altogether unsuitable. By using manual separation, the kernel yield in different pits was recorded as 60.21% (peach); 75.18% (plum) and 85.36% (apricot) (Table-4.6). Comparatively low kernel separation in this method was probably due to the presence of excessively crushed/pressed kernels, which were difficult to separate manually. However, by using specific gravity separation, all types of kernels whether crushed or whole floated at the top, which could easily be separated out. The efficiency of separation was evaluated by measuring the quantity of separated kernels from a crushed mass in a given period of time. The separated kernels were dried in the

Table 4.6: Standardization of a method for kernel separation from decorticated stones/ pits of apricot, peach and plum

Fruit kernel	Kernel recovery (%)					
	Manual Separation	Specific gravity separation (% Salt)				
		Water (1.000)	5% (1.036)	10% (1.078)	15% (1.115)	20% (1.158)
Apricot	85.36	No Separation	5.27	43.76	91.32	100.00
Peach	60.21	No Separation	15.67	47.37	79.93	99.98
Plum	75.18	No Separation	8.78	54.76	89.37	100.00

* Figures in parenthesis represent specific gravity of a brine solution

Table 4.7: Efficiency of kernel separation from decorticated stones/pits of apricot, peach and plum using different methods

Fruit kernels	Yield (g/hr)			
	Manual separation	Floatation in water	Specific gravity separation	Mean
Apricot	458.30 (2.66)	0.00 (0.00)	4467.00 (3.65)	1642.00 (2.10)
Peach	82.33 (1.91)	0.00 (0.00)	2783.00 (3.45)	955.20 (1.79)
Plum	136.30 (2.13)	0.00 (0.00)	1633.00 (3.21)	589.90 (1.78)
Mean	225.70 (2.23)	0.00 (0.00)	2961.00 (3.44)	

$CD_{0.05}$	Fruit (T)	:	(0.11)
	Method (M)	:	(0.11)
	T x M	:	(0.35)

* Figures in the parentheses are logarithmic transformed values

Table 4.8: Cost of kernel separation from decorticated (crushed) mass of apricot, peach and plum stones/pits.

Particulars	Quantity		Rate	Cost of kernel separation					
	Manual separation	Specific gravity separation		Manual separation			Specific gravity separation		
				Apricot	Peach	Plum	Apricot	Peach	Plum
Amount of salt required for 10 lt. of water @20% (Kg)	-	2	Rs.7/Kg	-	-	-	14	14	14
Manual labour/hr(no.)	1	2	Rs.55 /8hrs.	6.88	6.88	6.88	13.76	13.76	13.76
Electricity charges for drying of kernels/hr	-	1.5 units	Rs.0.65/unit	-	-	-	0.98	0.98	0.98
Total cost of kernel separation/hr	-	-	-	6.88	6.88	6.88	28.74	28.74	28.74
Quantity of kernel separation (g/hr)	-	-	-	458.30	82.33	136.30	4467.00	2783.00	1633.00
Unit cost of kernel separation (Rs./Kg)	-	-	-	15.01	83.57	50.48	6.43	10.33	17.60

*For specific gravity separation 20% salt solution equivalent to 1.158 specific gravity was used.

mechanical drier prior to their use for oil extraction purposes, thus the time involved during drying (to remove surface moisture) has also been taken into consideration while calculating the efficiency of kernel separation. It was observed that by using specific gravity separation method, 4.467 Kg apricot, 2.783 Kg peach and 1.633 Kg plum kernels were got separated within one hour against the respective mean values of 458.3g apricot, 136.30g plum and 82.33g peach kernels by using manual separation within the same period of time (Table-4.7). Thus the efficiency of the kernel separation has been increased by 9.75 times in apricot kernels, 7.24 times in plum kernels and 33.8 times in peach kernels. Besides, the specific gravity separation method has also drastically reduced the cost of kernel separation. It involved only Rs. 6.43 to Rs. 17.60 for each Kg of kernel separation against a value of as high as Rs. 15.01 to Rs. 83.57 required for manual separation of each Kg of stone fruit kernels (Table-4.8). Exceptionally high efficiency of kernel separation in peach kernels is due to the presence of large mass of shells in peach stones as such making its manual separation excessively difficult. Thus, on the basis of per cent kernel separation and increased efficiency of operation, the specific gravity separation method by using 20% salt solution with specific gravity of 1.158 has been optimised and recommended for use. However, in this method some undecorticated stones and few crushed shells also float on the top layer of the solution due to low density and got mixed up with the kernels (Plate – 5) for which further detailed studies are needed.

4.5 STANDARDIZATION OF A METHOD FOR KERNEL OIL EXTRACTION

Suitability of using oil press (Portable Power Ghani) for extraction of kernel oil was evaluated. Oil press was got fabricated from M/s. Kisan Krishi Yantra Udyog, Kanpur, India in which all contact parts within the crushing/pressing zone are made of wood, which is know to retain the quality characteristics better than that of commercially used *Kohlu* having all contact parts made of milled steel/stainless steel (Plate 6). Data on quality characteristics of kernel oil obtained from the oil press and by using soxhlet extraction apparatus is presented in Table-4.9. Average oil yield extracted by using oil press was 34.73% against the mean value of 46.28% oil obtained through solvent extraction method. The oil yield from kernels of different fruits was recorded as 38.97% (plum), 39.77% (apricot) and 42.77% (peach). In comparison to solvent extraction method, the kernel oil yield through oil press was generally low, which was probably due to the exertion of less pressure for oil extraction and the use of wooden contact parts, which are known to absorb some oil during the process of extraction.

Acid value which is the indicator of hydrolytic rancidity showed a mean value of 7.87 in kernel oil extracted by using solvent extraction as against a value of 8.39 in oil obtained through oil press. In different fruits, the acid value in kernel oils ranged between 2.35 to 19.30 (Table-4.9).

The mean iodine value representing the degree of unsaturation was recorded as 101.13 in the oil extracted from the soxhlet apparatus and 100.07 in the kernel oil obtained through the oil press. Among different fruits, the iodine value ranged between 98.0 to 103.5 and the difference between both the treatments was found to be non-significant (Table-4.9).

The kernel oil extracted by using the oil press exhibited the peroxide value 4.81 against the value of 3.97 found in the kernel oil obtained through solvent extraction method. The peroxide value being the inherent character of the individual oil was found to be 2.50 in plum oil, 4.43 in peach oil and 6.26 in apricot oil. The interaction within the type of oils and the method of extraction were however, found to be *non-significant* (Table-4.10).

The saponification value representing the average molecular weight of the oil exhibited no significant difference in the kernel oil extracted by using either solvent extraction or through oil press. Similarly, there was no significant difference in the saponification value of the kernel oil of different fruits i.e. apricot, peach and plum (Table-4.10).

Hydro-cyanic acid (HCN) is a water-soluble component which is released upon hydrolysis of amygdalin in the presence of inherent β-glucosidase during crushing of kernels. However, oil extracted by using solvent extraction apparatus did

Table 4.9: Effect of oil extraction method on the quality characteristics of oil from apricot, peach and plum

Fruit kernels	Yield of oil (%)			Acid value			Iodine value		
	Solvent extraction	Oil press	Mean	Solvent extraction	Oil press	Mean	Solvent extraction	Oil press	Mean
Apricot	45.03	34.50	39.77	2.57	2.93	2.75	101.10	100.40	100.75
Peach	48.93	36.61	42.77	18.84	19.75	19.30	104.10	102.00	103.05
Plum	44.87	33.07	38.97	2.19	2.50	2.35	98.20	97.80	98.00
Mean	46.28	34.73		7.87	8.39		101.13	100.07	

$CD_{0.05}$

	Yield of oil (%)	Acid value	Iodine value
Fruit kernel (T)	1.28	0.38	0.74
Method (M)	1.05	0.31	0.60
T x M	1.81	0.53	NS

Table 4.10: Effect of oil extraction methods on the quality characteristics of oil from apricot, peach and plum

Fruit kernels	Peroxide value			Saponification value			HCN (mg/100g)*		
	Solvent extraction	Oil press	Mean	Solvent extraction	Oil press	Mean	Solvent extraction	Oil press	Mean
Apricot	5.88	6.63	6.26	190.70	192.00	191.35	0.00 (16.78)	12.93 (21.08)	6.47 (18.93)
Peach	3.98	4.87	4.43	189.00	190.50	189.75	0.00 (16.78)	82.87 (65.55)	41.16 (4144)
Plum	2.05	2.94	2.50	189.20	191.00	190.10	0.00 (16.78)	23.37 (28.91)	11.69 (22.84)
Mean	3.97	4.81		189.63	191.17		0.00 (16.78)	39.72 (38.51)	

$CD_{0.05}$

Fruit kernel (T)	0.54	NS	(0.52)
Method (M)	0.44	NS	(0.42)
T x M	NS	NS	(0.74)

* Figures in the parenthesis are the arc sine transformation values

not show the presence of HCN, which probably got inactivated during heating of oil for evaporating the residual solvent and the moisture. The oil obtained through oil press on the other hand showed the presence of HCN, which might have been released during crushing of kernels (Table-4.10). Besides, during oil extraction little amount of warm water is also sprinkled on the kernels to facilitate the release of oil. Probably this operation might also cause hydrolysis of amygdalin thus showing the presence of hydro cyanic acid (a bittering/toxic principle). The extent of HCN found in kernel oil from different fruits ranged between 6.47-41.16 (mg/100g). Peach kernel oil showed the highest value of HCN (41.16 mg %) followed by plum kernel oil with the value of 11.69mg %. Apricot kernel oil on the other hand exhibited only 6.47mg HCN per 100g of oil (Table – 4.10). However, it is not unusual to find the presence of HCN in oil extracted by using oil press as in the commercial apricot oil extracted using Kohlu, HCN as high as 46.44mg % has been detected. Thus the presence of HCN in the kernel oil necessitates the need to develop a method for removal of toxic/bittering principle (detoxification) in fruit kernels prior to their use for oil extraction purposes.

4.6 STANDARDIZATION OF A METHOD FOR REMOVAL OF TOXIC/BITTERING PRINCIPLE (DETOXIFICATION) IN FRUIT KERNELS

The kernel oil from apricot, peach and plum stones extracted through oil press (Portable Power Ghani) showed the presence of hydro-cyanic acid (HCN) a bittering/toxic principle which is known to be produced due to the hydrolysis of amygdalin (Plate 11). Thus, this component is required to be removed from the kernels prior to their use in oil extraction purposes. The effectiveness of different methods used for the removal of toxic principle (detoxification) in different kernels has been evaluated as under:-

4.6.1 Immersion in water

The kernels of apricot, peach and plum fruits were immersed in water for different durations and the extent of presence of residual HCN was determined at periodic intervals. It was observed that the extent of complete removal of HCN varied with the amount of HCN initially present in different fruit kernels. Thus complete detoxification of kernels from the initial value of 72, 108 and 240mg HCN per 100g in apricot, plum and peach kernels was achieved within a period of 30, 45 and 60 minutes (Table – 4.11a). The removal of HCN in immersed kernels was probably due to the action of inherent β-glucosidase enzyme resulting in hydrolysis of amygdalin to HCN, which owing to its water-soluble nature got solublised in the water. Earlier, Schab and Yannai (1973) could achieve 99.3% removal of HCN by dipping the apricot kernels in water at a temperature of 55^{0}C and pH of 6.5 for two hours followed by steam distillation. Thus, our method of detoxification was more efficient, quick and easy to adopt on a semi-commercial scale.

4.6.2 Immersion in 20% salt solution

The extent of removal of HCN by immersing the kernels in 20% salt solution was evaluated. It was observed that within 5 minutes of immersion in salt solution (20%) the apricot kernels were completely detoxified. Similarly, depending upon the extent of initial value of HCN present, the plum and peach kernels took 15 and 30 minutes each for the complete removal of HCN (Table-4.11b). Earlier, Rothea (1945) achieved about 99% reduction in amygdalin in almond kernels by dipping them in salt solution.

4.6.3 Immersion in a solution of β-glucosidase (3500 units/mg)

The suitability of exogenous addition of β-glucosidase in different concentrations was optimised for the removal of HCN from kernels of different stone fruits. After five minutes of immersion, the kernels were analysed for the presence of HCN content. For different fruit kernels the complete removal of HCN was achieved by using exogenous β-glucosidase @ 0.5 ppm for apricot, 1.0 ppm for plum and 2 ppm for peach kernels (Table-4.11c). Thus, exogenous addition of β-glucosidase also proved to be the effective method for detoxification of kernels.

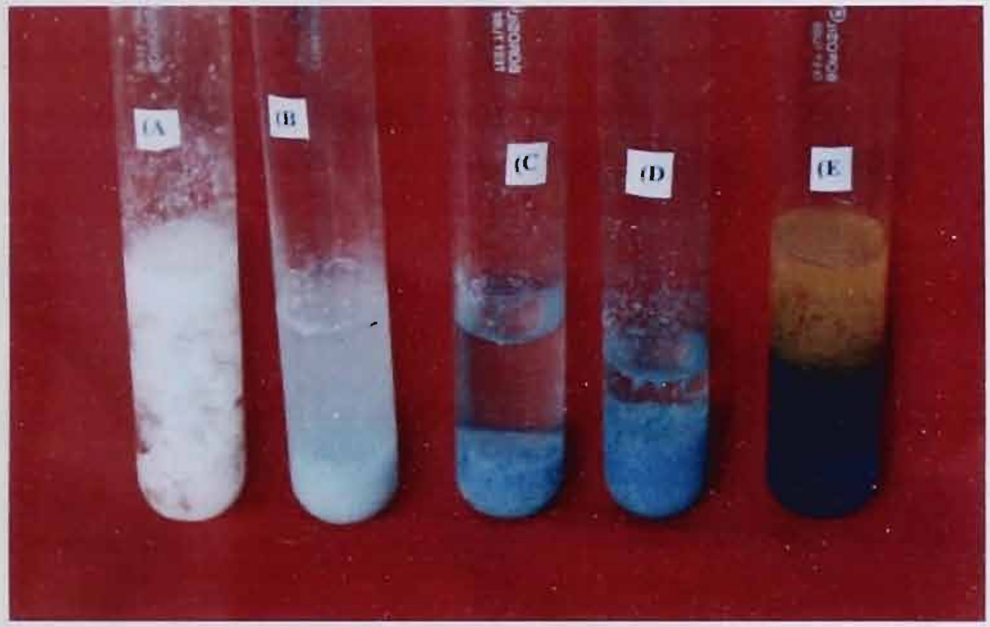

Plate 11. PRESCENCE OF HCN IN STONE FRUIT KERNELS AND OILS
(A. Almond ; B. Apricot ; C. Plum ; D. Peach ; E. Commercial Apricot Oil)

Table 4.11 (a): Effect of immersion in water on the concentration of hydro cyanic acid (mg/100g) in apricot, peach and plum kernels

Fruit kernels	Residual HCN (mg / 100g)*												
	Immersion in water (Duration, min)												
	0	5	10	15	20	25	30	35	40	45	50	55	60
Apricot	72.0	64.0 (11.1%)	39.0 (45.8%)	18.0 (75.0%)	10.0 (86.1%)	3.0 (95.8%)	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)
Peach	240.0	220.0 (8.33%)	195.0 (18.75%)	184.0 (23.33%)	125.0 (47.92%)	108.0 (55.0%)	94.0 (60.8%)	66.0 (72.5%)	43.0 (82.1%)	36.0 (85.0%)	12.0 (95%)	3.0 (98.8%)	0.0 (100%)
Plum	108.0	98.0 (9.3%)	75.0 (30.6%)	62.0 (42.6%)	43.0 (60.2%)	28.0 (74.1%)	20.0 (81.5%)	8.0 (92.6%)	4.0 (96.3%)	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)

* Figures in parenthesis indicate % detoxification

Table 4.11 (b): Effect of immersion in 20% salt solution on the concentration of hydro cyanic acid (mg/100g) in apricot, peach and plum kernels

Fruit kernels	Residual HCN (mg/100g)*						
	Immersion in 20% salt solution (Duration, min.)						
	0	5	10	15	20	25	30
Apricot	72.0	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)
Peach	240.0	196.0 (18.33%)	114.0 (52.5%)	82.0 (65.8%)	43.0 (82.1%)	12.0 (95.0%)	0.0 (100%)
Plum	108.0	76.0 (29.6%)	24.0 (77.8%)	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)

*Figure in parenthesis indicate % detoxification

Table 4.11 (c): Effect of immersion in β-Glucosidase (3500 units/mg) solution on the concentration of hydro cyanic acid (mg/100g) in apricot, peach and plum kernels

Fruit kernels	Residual HCN (mg/100g)* Immersion in β-Glucosidase solution **					
	Initial	Water	0.5 ppm	1 ppm	1.5 ppm	2 ppm
Apricot	72.0	64.0 (11.1%)	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)
Peach	240.0	220.0 (8.3%)	156.0 (35.0%)	84.0 (65.0%)	30.0 (87.5%)	0.0 (100%)
Plum	108.0	98.0 (9.3%)	38.0 (64.8%)	0.0 (100%)	0.0 (100%)	0.0 (100%)

*Figure in parenthesis indicate % detoxification
**Kernels were immersed in the solution for 5 min.

Table 4.11 (d): Effect of immersion in solution of Sodium thiosulphate on the concentration of hydro cyanic acid (mg/100g) in apricot, peach and plum kernels

Fruit kernels	Residual HCN (mg / 100g)* Immersion in sodium thiosulophate solution **					
	Initial	Water	0.1 %	0.2 %	0.3 %	0.4 %
Apricot	72.0	64.0 (11.1%)	0.0 (100%)	0.0 (100%)	0.0 (100%)	0.0 (100%)
Peach	240.0	220.0 (8.3%)	140.0 (41.7%)	84 (65.6%)	26.0 (5.0%)	0.0 (100%)
Plum	108.0	98.0 (9.3%)	34.0 (68.5%)	0.0 (100%)	0.0 (100%)	0.0 (100%)

...sis indicate % detoxification
d in the solution for 5 min.

4.6.4 Immersion in a solution of sodium thiosulphate

The possibility of treating fruit kernels with appropriate dose of sodium thiosulphate for their detoxification was explored as in human studies, sulphur containing compounds like sodium thiosulphate is often used as a part of antidotal treatment to ensure that there is ample sulphur available to detoxify all the cyanide (Salkowski and Penny, 1994). Depending upon the level of HCN initially present in the kernels, the dose of sodium thiosulphate was optimised to 0.1% for apricot, 0.2% for plum and 0.4% for peach, for the complete removal of bittering/toxic principle from the kernels (Table-4.11d). The detoxification is achieved probably due to reaction of sodium thiosulphate with the cyanide to form sodium thiocyanate.

Though all the four approaches were successful in complete removal of bittering/toxic principle, yet the one involving comparatively shorter duration for immersion and capable of being combined with other unit operations shall be most appropriate. Thus, immersion of fruit kernels in 20% salt solution for a period of 5 minutes for apricot, 15 minutes for plum and 30 minutes for peach during kernel separation has been optimised for the removal of HCN prior to use for oil extraction purposes.

4.7 STORAGE STUDIES OF KERNEL OILS

The storage stability of kernel oil extracted through Portable Power Ghani (oil press) was evaluated after packing in transparent and coloured bottles (Plate 12, 13) at periodic intervals of 0, 2, 4 and 6 months of storage at ambient temperature (10.2°C – 25.3°C). The results presented in the Table 4.12 to 4.17 are discussed as under.

4.7.1 Iodine value

With the advancement in period of storage the iodine value in kernel oil of different fruits exhibited slight decrease. After six months of storage, the values were found to be 93.1, 95.5 and 97.0 in plum, apricot and peach kernel oils respectively

Table 4.12: Effect of packaging material on the Iodine value of fruit kernel oils during storage

Storage Interval	Packaging Material	Apricot	Peach	Plum	Mean
Initial	Mean	100.4	102.0	97.8	100.1
2 Months	Transparent bottles	97.3	98.7	94.1	97.9
	Coloured bottles	98.3	99.9	95.4	97.9
	Mean	97.8	99.3	94.8	97.3
4 Months	Transparent bottles	91.8	94.3	90.4	92.2
	Coloured bottles	95.3	95.7	92.9	94.6
	Mean	93.5	95.8	91.7	93.4
6 Months	Transparent bottles	87.5	90.5	85.9	87.9
	Coloured bottles	92.7	92.7	90.6	92.0
	Mean	90.1	91.6	88.2	90.0
Packaging Materials (irrespective of storage)	Transparent bottles	94.2	96.4	92.1	94.2
	Coloured bottles	96.7	97.6	94.2	96.2
Grand Mean		95.5	97.0	93.1	

$CD_{0.05}$

Fruit oil (T)	: 0.30
Storage interval (S)	: 0.35
Packaging material (G)	: 0.25
T x S	: 0.60
T x G	: 0.42
S x G	: 0.50
T x S x G	: 0.86

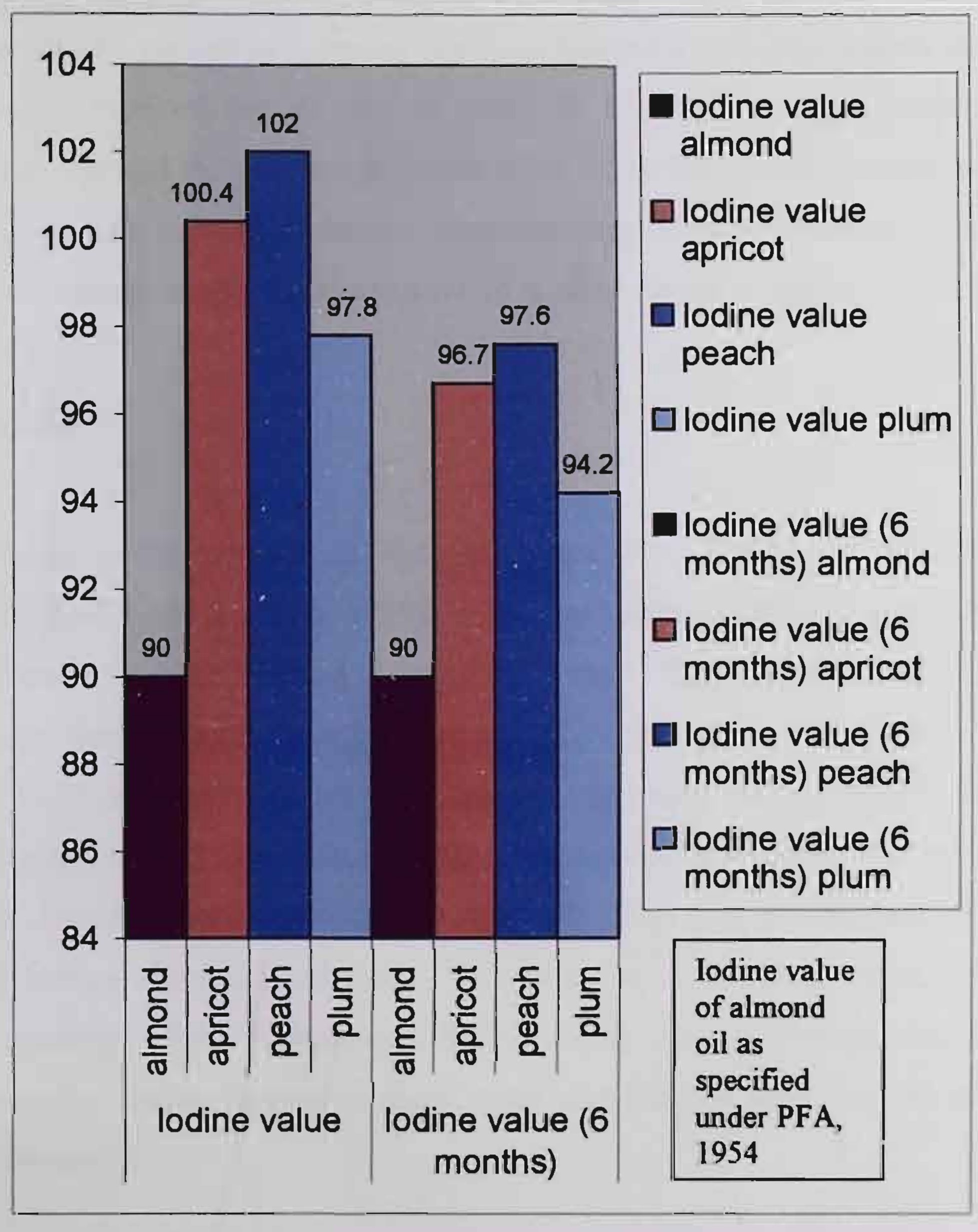

Fig 2 . IODINE VALUE OF KERNEL OILS DURING STORAGE

from their initial values of 97.8, 100.4 and 102.0 thus exhibiting a total decrease of about 4.8 to 4.94% (Table-4.12). Among packaging materials the coloured bottles exerted their significant influence in checking the fall of iodine value when compared with the iodine value of kernel oils packed in transparent bottles. According to PFA specifications, the iodine value in almond oil shall range between 90-109 (Anon., 1996). Thus kernel oils packed in coloured bottles exhibited their iodine values well within the range prescribed for almond oil (Fig. 2). However, those packed in transparent bottles showed the decrease in iodine value below 90.0, which might have been caused due to light induced oxidation. Thus, packing of oil in coloured bottles seems to be more appropriate for better retention of quality during storage.

4.7.2 Acid value

Acid value is the measure of hydrolytic rancidity of oils and generally increases during storage (Thimmaiah, 1999). In different kernels oils, the acid value exhibited an increase with the increase in period of storage. The mean value after six months of storage were found to be 4.26, 4.50 and 22.17 from their initial values of 2.50, 2.93 and 19.75 in kernel oil from plum, apricot and peach respectively (Table-4.13). The difference in acid value within different kernel oils was mainly due to the difference in acid value initially present in various oils. However, the oil packed in coloured glass bottles showed significantly less increase in the acid value, thus exhibiting its protective effect in preserving the oil during storage. Though, the oils packed in transparent bottles were also shelf stable and did not show any adverse change during storage.

4.7.3 Peroxide value

The peroxide value representing the measure of peroxides formed in the oils during storage showed some increase in all kernel oils with the increase in period of storage. Irrespective of packaging material, the mean peroxide value in kernel oils from plum, peach and apricot was recorded as 9.45, 9.68 and 12.67 respectively from its initial value of 2.94, 4.87 and 6.63 in respective oils (Table-4.14). Among the packaging materials the oils packed in amber coloured bottles showed comparatively less increase in peroxide value than those packed in transparent glass bottles. However, there was not much difference in a parent quality characteristic of kernel oils packed in either of the packaging material. Jacobs (1958) had also specified the maximum peroxide value of about 50 for saturated fatty acids and 125 for unsaturated fatty acids to consider it rancid (Fig. 3). Thus, the peroxide values of our oils were well below the threshold limit of the rancidity.

4.7.4 Saponification value

Saponification value in kernel oil from different fruits showed a marginal increase during storage. However, during the entire period of storage, the packaging material exerted negligible influence on the saponification value of the kernel oils. Perusal of data (Table-4.15 and Fig. 4) further indicated that the mean saponification value in oils remained well within the range of saponification value specified for almond oil under the Prevention of Food Adulteration Act (Anon., 1996).

4.7.5 Oleic acid

Oleic acid is the monoenoic acid and constitutes the major portion of the unsaturated fatty acid in the kernel oils. The mean value of the different fruits ranged between 63.23 to 69.27%, which experienced slight decrease during the period of storage. After 6 months of shelf life the values of oleic acid in three different oils were found to vary between 60.25 to 66.61%, thus registering a decrease of 3.84%-5.6% (Table-4.16). However, the oils packed in coloured bottles showed comparatively less change in oleic acid during storage than that packed in transparent bottles. The decrease in oleic acid was probably due to the formation of peroxides, which are known to be unstable and later break down to simpler compounds of short chain fatty acids (Nawar, 1985).

4.7.6 Linoleic acid

In contrast to oleic acid, the linoleic acid content in kernel oils experienced greater changes during storage at ambient temperature. After six months of storage

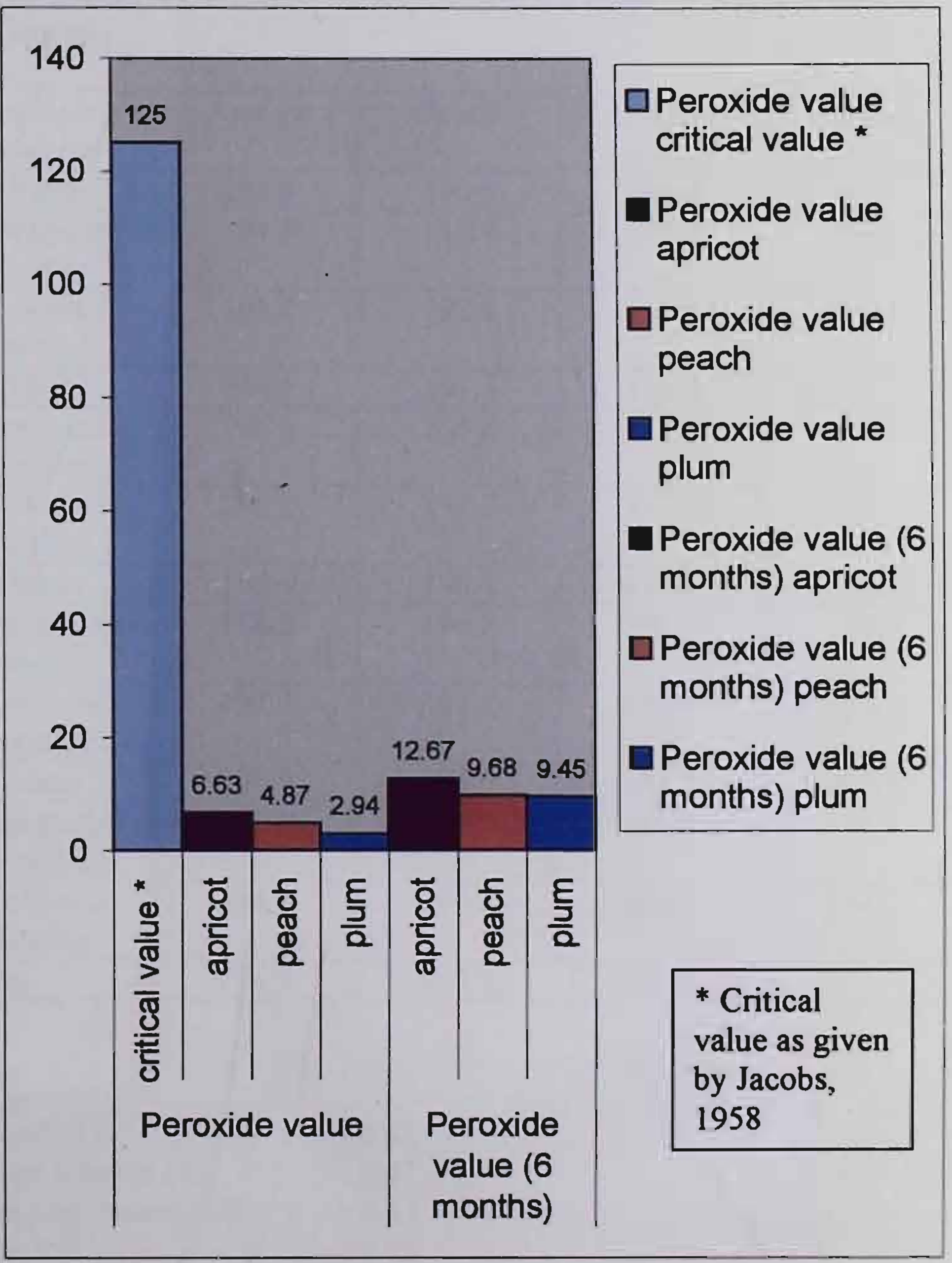

Fig 3 . PEROXIDE VALUE OF KERNEL OILS DURING STORAGE

Table 4.15: Effect of packaging material on Saponification value of fruit kernel oils during storage

Storage Interval	Packaging Material	Apricot	Peach	Plum	Mean
Initial	Mean	192.0	190.5	191.0	191.2
2 Months	Transparent bottles	194.5	193.4	193.6	193.8
	Coloured bottles	193.7	192.8	192.9	193.1
	Mean	194.1	193.1	193.3	193.5
4 Months	Transparent bottles	196.0	195.5	195.9	195.8
	Coloured bottles	195.3	194.7	194.8	194.9
	Mean	195.6	195.1	195.4	195.4
6 Months	Transparent bottles	198.2	198.8	198.5	198.5
	Coloured bottles	197.7	197.1	197.3	197.3
	Mean	197.9	197.9	197.9	197.9
Packaging Materials (irrespective of storage)	Transparent bottles	195.2	194.6	194.8	194.8
	Coloured bottles	194.7	193.8	194.0	194.1
Grand Mean		194.9	194.2	194.4	

$CD_{0.05}$

Fruit oil (T)	: 0.41
Storage interval (S)	: 0.47
Packaging material (G)	: 0.33
T x S	: 0.82
T x G	: 0.58
S x G	: 0.66
T x S x G	: 1.12

Table 4.16: Effect of packaging material on Oleic Acid content (%) of fruit kernel oils during storage

Storage Interval	Packaging Material	Apricot	Peach	Plum	Mean
Initial	Mean	69.27	64.23	63.83	65.78
2 Months	Transparent bottles	68.07	63.70	63.07	64.95
	Coloured bottles	69.17	64.02	63.20	65.46
	Mean	68.62	63.86	63.14	65.21
4 Months	Transparent bottles	67.67	62.10	61.96	63.91
	Coloured bottles	68.55	63.19	62.36	64.70
	Mean	68.11	62.64	62.16	64.31
6 Months	Transparent bottles	65.82	60.55	59.72	62.03
	Coloured bottles	67.40	61.97	60.78	63.38
	Mean	66.61	61.26	60.25	62.71
Packaging Materials (irrespective of storage)	Transparent bottles	67.71	62.24	62.15	64.17
	Coloured bottles	68.60	63.35	62.54	64.83
Grand Mean		68.15	63.00	62.35	

$CD_{0.05}$

Fruit oil (T)	: 0.85
Storage interval (S)	: 0.98
Packaging material (G)	: NS
T x S	: 1.71
T x G	: NS
S x G	: 1.39
T x S x G	: NS

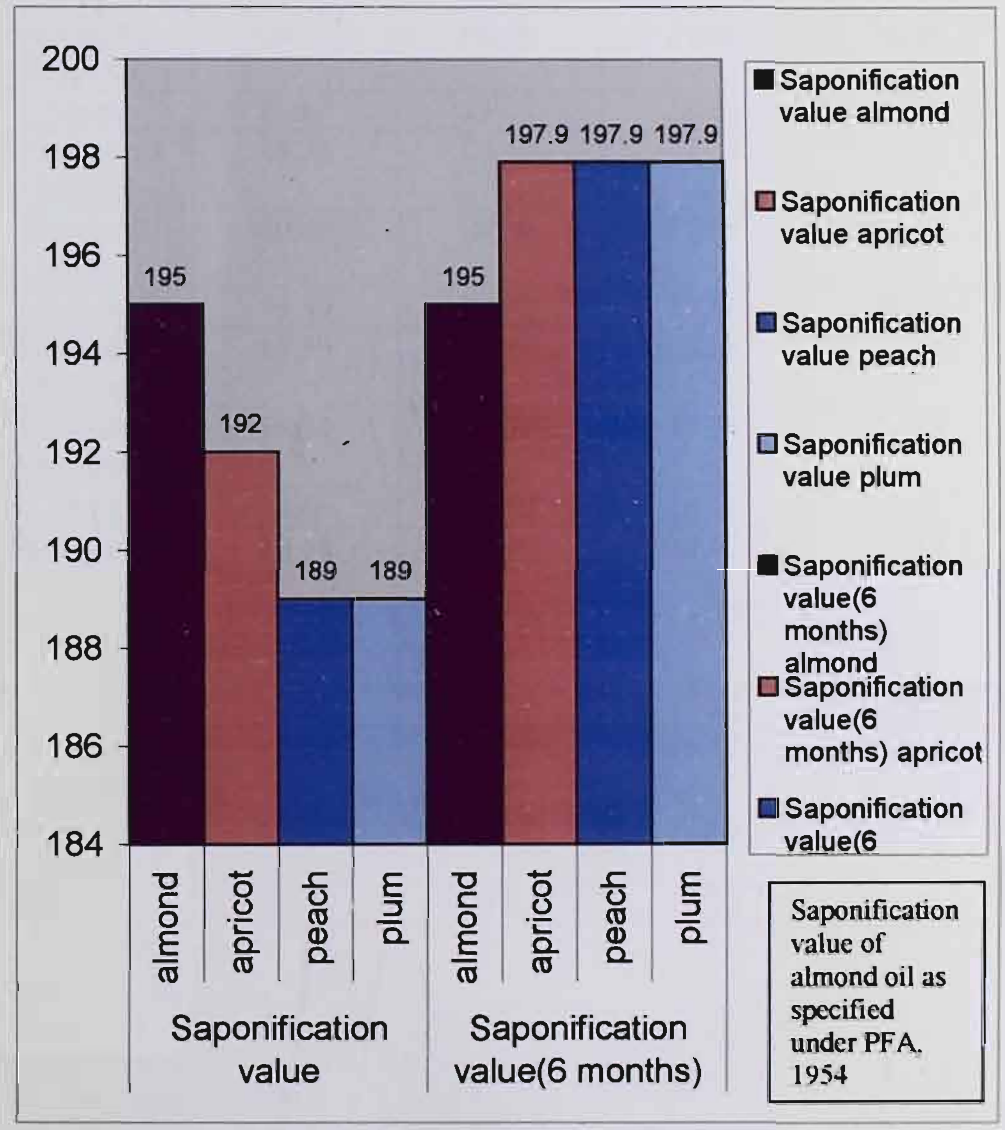

Fig 4 . SAPONIFICATION VALUE OF KERNEL OILS DURING STORAGE

Table 4.17: Effect of packaging material on Linoleic Acid content (%) of fruit kernel oils during storage

Storage Interval	Packaging Material	Apricot	Peach	Plum	Mean
Initial	Mean	20.67	25.07	18.85	21.53
2 Months	Transparent bottles	19.33	24.10	17.37	20.27
	Coloured bottles	20.05	24.86	17.99	20.97
	Mean	19.69	24.48	17.68	20.62
4 Months	Transparent bottles	17.99	22.80	16.08	18.96
	Coloured bottles	19.34	24.10	17.14	20.19
	Mean	18.66	23.45	16.61	19.58
6 Months	Transparent bottles	16.18	21.40	14.97	17.52
	Coloured bottles	18.23	23.20	16.67	19.37
	Mean	17.20	22.30	15.82	18.44
Packaging Materials (irrespective of storage)	Transparent bottles	18.54	23.34	16.82	19.57
	Coloured bottles	19.57	24.31	17.66	20.51
Grand Mean		19.06	23.82	17.24	

$CD_{0.05}$

Fruit oil (T)	: 0.49
Storage interval (S)	: 0.57
Packaging material (G)	: 0.40
T x S	: NS
T x G	: NS
S x G	:0.80
T x S x G	:NS

Table 4.18: Cost of production of kernel oil from apricot, peach and plum stones*

Particulars	Quantity			Rate (Rs/unit)			Amount (Rs.)		
	Apricot	Peach	Plum	Apricot	Peach	Plum	Apricot	Peach	Plum
Fruit stones/pits (Kg)	100.00	200.00	150.00	2.50/Kg	1.00/Kg	1.00 /Kg	250.00	200.00	150.00
Cost of decortication	100.00	200.00	150.00	0.39/Kg	0.17/Kg	0.26/Kg	39.00	34.00	39.00
Kernel recovery(Kg)	30.00	11.00	14.25	-	-	-	-	-	-
Cost of kernel separation	30.00	11.00	14.25	6.43/Kg	10.33/Kg	18.51/Kg	192.90	113.63	250.8
Kernel oil yield (lt)	12.0	4.40	5.20	-	-	-	-	-	-
Packaging material (200 ml bottle)	60	22	26	1	1	1	60.00	22.00	26.00
Crown corks	60	22	26	0.25	0.25	0.25	15.00	5.50	6.50
Electricity charges(for oil extraction)	9 units	3 units	3 units	0.65/unit	0.65 unit	0.65\unit	5.85	1.95	1.95
Total	-	-	-	-	-	-	562.85	377.08	474.25
Processing charges including depreciation cost @ 20 %	-	-	-	-	-	-	112.57	75.42	94.85
Total cost of oil packed in 200 ml bottles	-	-	-	-	-	-	675.42	452.50	569.1
Profit @ 20%	-	-	-	-	-	-	135.08	90.50	113.82
Total cost of production	-	-	-	-	-	-	810.50	543.00	682.92
Sale price per bottle** (200 ml)	-	-	-	-	-	-	13.51	24.68	26.27

*Oil extraction by using oil press

** Prevalent sale price of chulli (wild apricot) oil is Rs. 140 per bottle of 650ml capacity

Plate 12. STORAGE OF KERNEL OILS IN TRANSPARENT BOTTLES

Plate 13. STORAGE OF KERNEL OILS IN COLOURED BOTTLES

period the values in plum, apricot and peach kernel oils were found to be 15.82, 17.20 and 22.30 % respectively. Packing of kernel oils in coloured bottles however showed comparatively less decrease in linoleic acid contents in comparison to the oil packed in transparent bottles (Table-4.17). Further, comparatively higher decrease in linoleic acid in kernel oils during storage than that of oleic acid corroborated the findings of Chan and Levett (1977) and Labuza (1971), who had observed that linoleic acid was 20 times more susceptible than oleic acid to oxidation and other changes during storage. Further, on the basis of physical appearance and other attributes, apparently there was not much difference in the quality of all the kernel oils packed either in transparent or coloured glass bottles and the oil remained shelf stable during the entire period of storage study.

4.8 COST OF PRODUCTION

The cost of production of oil from apricot, peach and plum stones by using oil press has been calculated by taking into consideration all the possible inputs viz., cost of raw material (stones), cost involved during decortication, kernel separation and oil extraction etc. The processing charges @ 20% for labour and other miscellaneous expenses including depreciation were added to the total expenditure. The sale price for each glass bottle of 200 ml capacity was calculated after adding 20% profit margin. It is evident from the Table – 4.18 that out of 100, 200 and 150 Kg of apricot, peach and plum stones, about 30, 11 and 14.25 Kg of kernels are obtained which yield upto 12, 4.4 and 5.2 litres of kernel oil respectively. The sale price of kernel oil for each glass bottle of 200 ml capacity after adding 20% profit margin for different fruits has been calculated to be Rs. 13.51 for apricot oil, Rs. 24.68 for peach oil and Rs. 26.27 for plum kernel oil. The prevalent sale price of *Chulli* (wild apricot) has been found to be 140.00 per bottle of 650 ml capacity, which works to more than Rs. 40.00 per 200 ml capacity glass bottles. Thus, apricot, peach and plum stones can successfully be utilised for the extraction of kernel oil by using standardised method of decortication, kernel separation and oil extraction.

SUMMARY& CONCLUSION

5

SUMMARY AND CONCLUSION

Studies on "Extraction and evaluation of stone fruit kernel oils" were conducted in the Department of Postharvest Technology, Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan, H.P. (India) during the years 2000-2002. Stones/pits of different cultivars of apricot, peach and plum were collected from various locations in Himachal Pradesh and evaluated for oil extraction purpose using soxhlet extraction apparatus. For optimising methods for commercial oil extraction, the stones/pits of peach, apricot and plum left after processing of fruits were collected from the H.P. Government Fruit Canning Unit, Rajgarh (Distt. Sirmour); hpmc Fruit Processing Plant, Parwanoo (Distt. Solan) and hpmc Fruit Processing Plant, Jarol (Distt. Mandi) respectively. The method for crushing of stones/pits was standardized by designing and fabricating a decorticator (stone crusher) from Prototype Manufacturing Unit, Division of Agricultural Engineering, Indian Agricultural Research Institute, New Delhi. The suitability of the decorticator was evaluated against the manual method of breaking/crushing of stones/pits. The technique for separation of kernels from the crushed (decorticated) stones/pits was optimised using different combinations of manual separation, floatation in water and specific gravity separation. The removal of toxic/bitter principle (HCN) in stone fruit kernels involved the use of different treatments viz., immersion either in water, 20% salt solution, in a solution of β-glucosidase or sodium thiosulphate. The suitability of using oil press (Portable Power Ghani) having all contact parts made of wood (M/s Kisan Krishi Yantra Udyog, Kanpur) commonly used for sarson oil was evaluated for oil extraction from apricot, peach and plum kernels. Studies on evaluating the storage stability of oil expressed through oil press were conducted at periodic intervals of 0, 2, 4 and 6 months after its packaging in transparent and coloured glass bottles and storing at ambient temperature (10.2°C to 25.3°C). The results of this study on evaluation of stone fruit kernels for oil extraction, decortication, kernel separation, detoxification, commercial oil expression and storage stability are summarised briefly as under:-

1. The stone fruit pits and their kernels used in the study showed great variation in their physico-chemical characteristics. The stones of peaches were the largest with their size parameters ranging between 35.22-39.41mm length; 24.00-24.74 mm breadth and 17.13-17.67 mm thickness. The peach stones were also harder to break, owing to their maximum shell thickness of 4.84-5.64 mm. However, the kernels from apricot stones were larger in volume with their length x breadth x thickness dimensions ranging between 12.55 x 8.85 x 6.42 to 13.88 x 9.77 x 5.27 cubic mm. Besides, they were also heavier with their mean weight ranging between 0.35-0.42 g, followed by kernels of peach (0.28-0.35 g) and plums (0.07-0.26 g). The apricot stones had maximum recovery of kernels (28.0-30.16%) followed by plums (9.07-20.75%) and least in peach stones (5.67-5.87%). However, the oil recovery was highest in peach stones (44.71-51.08%), followed by apricots (43.03-44.36%) and plums (39.73-43.63%). Further all the cultivars of stone fruits showed the presence of hydro cyanic acid (HCN) a bittering/toxic principle in their kernels.
2. On the basis of the physico-chemical characteristics of stone fruits and their production figures, an oil yield of approximately 29.4 MT and 438.6MT is expected in Himachal Pradesh and India respectively. Thus, there exists an ample scope for utilisation of stone fruit kernels in extraction of oils for food and other industrial purposes. The potential cultivars whose stones are available for oil extraction are *Chulli* (apricot), *Santa Rosa* (plum) and *Elberta & July Elberta* (peach).
3. The visual appearance of kernel oil of all the stone fruits was yellow except *Santa Rosa* plum which had a reddish yellow colour. The specific gravity, refractive index and butyrorefractometer reading in all the kernel oils ranged between 0.89-0.92, 1.46-1.47 and 49.5-69.5 respectively. The acid value was maximum in peach oil (6.17-25.61) followed by kernel oil from apricot and in plum kernel oil. The peroxide value in different oils ranged within The saponification value and iodine value in most of the kernel oils hin the range of saponification and iodine value specified for almond der Indian Food Laws. However, kernel oil from *New Castle* apricot,

July Elberta peach and *Methley* plum showed slightly higher iodine value. All the kernel oils from stone fruits were regarded as a good source of unsaturated fatty acids with their oleic and linoleic acid contents ranging between 59.67 to 72.59% and 15.27 to 30.00% respectively.

4. The mechanical decorticator developed for crushing/decortication of stones was found to be the most efficient in operation with crushing efficiency of 42.02 to 94.67 Kg of stones per hour against manual crushing of 2.25-6.03 Kg stones within the given time interval. The clearance between the two rollers has been optimised to 8.68 mm for apricot stones, 6.93 mm for plum stones and 12.67 mm for peach stones. The cost of decortication for each Kg of stone by mechanical decorticator was only Rs. 0.20 to Rs. 0.45 /Kg against a value of Rs. 1.35 to Rs. 3.61 required for manual crushing of each Kg of stones/pits.
5. Specific gravity separation involving immersion of crushed/decorticated mass of stones in 20% salt solution (1.158 specific gravity) brought about complete separation of kernels which floated on the solution while shells settled at the bottom. Manual separation besides, being too laborious and time consuming could separate only 60.21 to 85.36% of the kernels from the crushed mass. Thus, the specific gravity separation brought about 9.7 times, 7.24 times and 33.8 times improvement in kernel separation within one hour from the crushed mass. of apricot, plum and peach stones respectively over manual method. Further, it also brought about significant reduction in the cost of kernel separation as it took only Rs. 6.76 to Rs. 18.51 for each Kg of kernel separated against a cost of Rs. 17.74 to Rs. 98.75 for manual separation of kernels.
6. The oil press (Portable Power Ghani) having all contact parts made of wood (within the crushing zone), showed an oil yield of 33.07 to 36.61% against the recovery of 44.87-48.93% oil obtained by using soxhlet extraction apparatus. The oils extracted by using either of the method did not show any appreciable difference in their quality characteristics. However, the kernel oil obtained through oil press did show the presence of hydro cyanic acid a bittering/toxic principle. In kernel oil of different fruits HCN contents were recorded as 6.47 mg % in apricot oil, 11.69 mg% in plum oil and 41.16 mg% in peach kernel oil.

. The detoxification of stone fruit kernels prior to their use for oil extraction was achieved successfully by using all the four methods viz., immersion of kernel detoxification, commercial oil expression and storage stability are summarised briefly as under:-

1. The stone fruit pits and their kernels used in the study showed great variation in their physico-chemical characteristics. The stones of peaches were the largest with their size parameters ranging between 35.22-39.41mm length; 24.00-24.74 mm breadth and 17.13-17.67 mm thickness. The peach stones were also harder to break, owing to their maximum shell thickness of 4.84-5.64 mm. However, the kernels from apricot stones were larger in volume with their length x breadth x thickness dimensions ranging between 12.55 x 8.85 x 6.42 to 13.88 x 9.77 x 5.27 cubic mm. Besides, they were also heavier with their mean weight ranging between 0.35-0.42 g, followed by kernels of peach (0.28-0.35 g) and plums (0.07-0.26 g). The apricot stones had maximum recovery of kernels (28.0-30.16%) followed by plums (9.07-20.75%) and least in peach stones (5.67-5.87%). However, the oil recovery was highest in peach stones (44.71-51.08%), followed by apricots (43.03-44.36%) and plums (39.73-43.63%). Further all the cultivars of stone fruits showed the presence of hydro cyanic acid (HCN) a bittering/toxic principle in their kernels.
2. On the basis of the physico-chemical characteristics of stone fruits and their production figures, an oil yield of approximately 29.4 MT and 438.6MT is expected in Himachal Pradesh and India respectively. Thus, there exists an ample scope for utilisation of stone fruit kernels in extraction of oils for food and other industrial purposes. The potential cultivars whose stones are available for oil extraction are *Chulli* (apricot), *Santa Rosa* (plum) and *Elberta & July Elberta* (peach).
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July Elberta peach and *Methley* plum showed slightly higher iodine value. All the kernel oils from stone fruits were regarded as a good source of unsaturated fatty acids with their oleic and linoleic acid contents ranging between 59.67 to 72.59% and 15.27 to 30.00% respectively.

4. The mechanical decorticator developed for crushing/decortication of stones was found to be the most efficient in operation with crushing efficiency of 42.02 to 94.67 Kg of stones per hour against manual crushing of 2.25-6.03 Kg stones within the given time interval. The clearance between the two rollers has been optimised to 8.68 mm for apricot stones, 6.93 mm for plum stones and 12.67 mm for peach stones. The cost of decortication for each Kg of stone by mechanical decorticator was only Rs. 0.20 to Rs. 0.45 /Kg against a value of Rs. 1.35 to Rs. 3.61 required for manual crushing of each Kg of stones/pits.
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7. The detoxification of stone fruit kernels prior to their use for oil extraction was achieved successfully by using all the four methods viz., immersion of kernel

paste in water, in 20% salt solution, in a solution of β-glucosidase or sodium thiosulphate. However, immersion of kernels in 20% salt solution for comparatively a shorter duration of 5 minutes (crushed apricot kernels), 15 minutes (crushed plum kernels) and 30 minutes (crushed peach kernels) has been optimised for detoxification as it can also be combined with the previous unit operation of kernel separation using specific gravity separation method.

8. The storage of kernel oil expressed by using oil press up to 6 months did not exhibit any adverse changes in chemical constituent of the oil. Further all the oils packed either in transparent or coloured bottles remained well within the minimum specifications for almond oil specified under the Prevention of Food Adulteration Act and rules for different constituents. However, packing in coloured bottles did show slight improvement in retention of some of the chemical attributes of the kernel oil.
9. The cost of production of the kernel oil from apricot, plum and peach stones after adding 20% each of processing charges and profit margins has been calculated to Rs. 13.51, 24.68 and 26.27 for each glass bottle of 200ml capacity respectively while the prevalent sale price of *Chulli* (wild apricot) in some tribal areas of Himachal Pradesh has been reported to be Rs. 140 per 650 ml bottle (equivalent to Rs. 43 per 200 ml glass bottle). Thus, utilisation of stone fruit kernels for extraction of oil seems to be a quite profitable venture.

Conclusion

The present investigation on the "Extraction and evaluation of stone fruit kernel oils" have thus shown that about 500 MT of stones/pits in Himachal Pradesh and more than 9500 MT of stones/pits in India can successfully be utilised for extraction of about 29 and 438 MT of oil respectively. The decortication of pits of all the stone fruits using mechanical decorticator and the separation of the kernels by specific gravity separation method using 20% salt solution (specific gravity 1.158) has been optimised. The detoxification of all the kernels by immersing in 20% salt solution as that used for kernel separation for varying period of time resulted in complete removal of toxic principle i.e. hydro cyanic acid (HCN) from the kernels.

The kernels after drying can successfully be utilised for oil extraction purpose by using the oil press (Portable Power Ghani). Further, all the kernel oils packed in transparent or coloured bottles were shelf stable during storage of six months. Thus, utilisation of stone fruit kernels for extraction of oils seems to be a profitable proposition for the efficient utilisation of stones/pits of apricot, peach and plum which otherwise is thrown as a waste. Preparation of such oils may also open an avenue for their utilisation in various purposes viz., pharmaceuticals, cosmetics and in food industry. Establishment of oil extraction unit adjoining fruit processing unit not only supplements processor's income also help in checking environment pollution. However, pilot scale testing of the technology is required before its final adoption by the industry.

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* *Original not seen*

ANNEXURE

ANNEXURE

Mean monthly metrological data during the study period
(January, 2002-July, 2002)

Month	Temperature (°C)		Relative Humidity(%)
	Maximum	Minimum	
January	18.2	2.3	63
February	19.5	4.5	65
March	24.4	8.8	61
April	30.0	12.9	52
May	33.0	17.0	41
June	31.4	19.1	60
July	30.5	20.2	67

Source : Meteorological Observatory, Department of Soil Science and Water Management, Dr, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Solan (H.P.)

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