IJP (2021), Vol. 8, Issue 9 **(Review Article)**

International Journal of Pharmacognosy

Received on 07 July 2021; received in revised form, 17 September 2021; accepted 19 September 2021; published 30 September 2021

SCOPE OF BLACK PEPPER *PIPER NIGRUM* L. EXTRACT INPEST CONTROL

Nitu Sinha and Sonali Ray *

Tea Chemistry and Pharmacology Laboratory, Department of Tea Science, University of North Bengal, Raja Rammohunpur, Bairatisal - 734013, West Bengal, India.

Keywords:

Black pepper, Piperine, Pest control, Mode of action, Extraction.

Correspondence to Author:
Dr. Sonali Ray

Tea Chemistry and Pharmacology Laboratory, Department of Tea Science, University of North Bengal, Raja Rammohunpur, Bairatisal - 734013, West Bengal, India.

E-mail: sonaliray@nbu.ac.in

ABSTRACT: Black pepper (*Piper nigrum* L.) is a widely used spice around the world. It has also been explored for its biological properties and bioactive compounds. The significance and efficacy of black pepper and its bioactive compounds in insecticidal, antiviral, antibacterial, antifungal infections are well-acknowledged throughout the world. The secondary metabolites of *Piper nigrum* L. are responsible for these activities. Piperine is one of the potent components in pest control due to its pungent smell. Eventually, efficient and optimal extraction methodologies are obligatory for the most competent functionalization of black pepper extract. Plausible reports are supporting its impact and application as a natural pesticide to control the pest abundance. The novel, environmentally benevolent natural pesticides are essential for pest control. In this review paper, we tried to summarize all potential, rapid, simple, feasible, and sustainable methods for black pepper extraction, isolation, and mode of action as a pest regulator. Lethal concentration, doses, and application time are the major regulating factors of a natural pesticide. Changes in the growth and developmental stages of target pests consequently fluctuate *Black pepper* extract's application rate and efficiency. It also contains bio-enhancing properties. Synergistic effects of piperine along with other secondary components of black pepper are the way to chemical-free natural pesticides.

INTRODUCTION: Black Pepper is the dried, unripe fruit of the perennial plant *Piper nigrum* L and belongs to the family *Piperaceae*. It becomes the "king of spices" due to its variety of uses in daily life as well as medicines [1] and bio-pesticides [2-12]. In Indian as well as Asian cuisines, black pepper is used vividly and acts as a taste enhancer and exported internationally [13].

QUICK RESPONSE CODE

DOI: 10.13040/IJPSR.0975-8232.IJP.8(9).351-60

The article can be accessed online on www.ijpjournal.com

DOI link: http://dx.doi.org/10.13040/IJPSR.0975-8232.IJP.8(9).351-60

South India, especially the Western ghat coastal region, is the main production area of black pepper, Kerala, Karnataka, Konkan, Tamil Nadu, Pondicherry & Andaman Nicobar islands are significant producers [14]. Now it is grown throughout the Asia-pacific region of tropical countries. West Indies and Sri Lanka also produce a good amount of black *Pepper* [15].

Piper nigrum is a familiar species of genus piper because of its high economic, commercial, and medicinal values and is highly exported among the other spices from India [16]. From the age of Ayurveda to the era of modern science, black pepper is indispensable. It is a flowering vine and its dried unripe berries are commercially used as peppercorn [17]. In recent years the value of black pepper has been increasing due to its pungency, flavor, and health benefits. This typical pungency is endorsed to the existence of a naturally occurring alkaloid, known as piperine [18] as well as volatile essential oils. Piperine is the major secondary metabolite of black pepper that has insecticidal activity, needs to be extracted and isolated for the bio-pesticide preparation [19]. Essential oils procured from black pepper have insecticidal, antibacterial, antiviral, antifungal properties [20, 22].

Secondary metabolites from plants are meant to defend it. Knowledge of the phytochemicals will be valuable for researchers to produce novel compound substances. The use of chemical and synthetic pesticides as pest management systems imposes potential adverse effects on the environment and human health. It also increases the production costs of agriculture. Plant-derived bio-pesticides nowadays emerged as a viable and sustainable solution [23]. In this study, we tried to summarize different extraction procedures of piperine extraction from black pepper and its mode of action on the pest population. Well-organized, rapid, cost-efficient and simple technique development and its various pest repellent activities are the foremost endeavors of this review study.

Chemical Constituents of Black Pepper: Various components of black pepper are responsible for its flavor, aroma, color and pungency. These components are easily identifiable from gas chromatography-mass spectroscopy (GC-MS) analysis [17].

Different varieties of black pepper have different components. Among the chemical constituents of black pepper, piperine is one of the most potent and abundant alkaloids. Piperine act as a biomarker. It can increase the bioavailability of drugs [15] and most importantly it has insecticidal properties [24].

Systematic position of *Piper nigrum* [25]:

Kingdom	:	Plantae
Class	:	Equisetopsida
Subclass	:	Magnoliidae
Superorder	:	Magnolianae
Order	:	Piperales
Family	:	Piperaceae
Genus	:	*Piper*
Species	:	*nigrum*

TABLE 1: DIFFERENT VARIETIES OF BLACK PEPPER AND THEIR RESPECTIVE CHEMICAL CONSTITUENTS

Name of different varieties of black pepper	Main elements	Method	Refernce
Thevan mundi	β pinene (3.7 to 8.7%), sabinene (4.5 to 16.2%), liinonene (8.3 to 18.0%), β caryophyllene (20.3 to 34.7%).	GC and GC-MS	26
Poonjwan munda	β ocimene (<0.1 to 12.0 %), β pinene (6.0 to 11.7%) liinonene (14.9 to 15.8%), β caryopliyllene (24.4 to 30.8%), elemol (1.2 to 6.8%).	GC and GC-MS	26
Valiakaniakadan	δ 3 carene (0 to 10.5%), α pinene (2.9 to 6.3%), liinonene (12.9 to 18.6%), sabinene (12.9 to 17.1%), β caryophyllene (23.0 to 38.4%).	GC and GC-MS	26
Subhakara	α pinene (3.2 to 7.0%), β pinene (7.6 to 9.6%), δ 3 carene (19.0 to 23.4%), limonene (18.3 to 22.7%), β caryophyllene (7.6 to 21.3%) caryophyllene oxide (0.4 to 6%)	GC and GC-MS	26
Karimunda, Kalluvally Arakulam munda and Thommankody	δ 3 carene (O.1 to 21.0%), β pinene (2.0 to 15.270 %), α pinene (2.4 to 11.4%), limonene (9.4 to 21.9) β caryophyllene (19.8 to 45.3%).	GC and GC-MS	27
Kottanadan	β pinene (7.5 to 15.4%), β caryophyllene (8.9 to 24.1%), sabinene (11.2 to 22.6%), limonene (12.7 to 23.8%).	GC and GC-MS	28
Ottaplackal	sabinene (0.1 to 26.8%) β pinene (3.8 to 11.7%), myrcene (0 to 18.6%), limonene (15.5 to 21.7%), β caryophyllene (15.5 to 21.7%)	GC and GC-MS	28
Kuthiravally	β pinene (3.8 to 10.9%), limonene (9.0 to 16.9%), β caryophyllene (29.0 to 46.0%).	GC and GC-MS	28
Cheriakaniakadan	β pinene (7.7 to 11.2%), sabinene (9.7 to 22.3%), limonene (14.7 to 17.8%), β caryophyllene (17.4 to 23.1%).	GC and GC-MS	28
Panniyur-1, Panniyur-2,	β cymene (0.0 to 0.18%), myrcene (2.20 to 2.30%), α pinene	GC-MS	29

Panniyur-3 and culture 239	(5.07 to 6.18%), sabinene (8.50 to 17.16%), β pinene (9.16 to 11.08%), limonene (21.06 to 22.71%), β caryophyllene (21.59 to 27.70%), oxygenated constituents (3.39 to 5.68%). Culture - 239 derived oil contained β caryophyllene (21.19%), α pinene (5.32%), sabinene (1.94%), β pinene (6.40%), myrcene (8.40%), β cymene (9.70%), limonene (16.74%) and oxygenated constituents (4.41%).		
Vellanamban	β pinene (3.9 to 10.9%), sabinene (3.9 to 18.8%), limonene (8.3 to 19.8%), β caryophyllene (28.4 to 32.9%).	GC and GC-MS	30
Sreekara	β pinene (0 to 11.2%), limonene (20.1 to 22.1%), β caryophyllene (16.8 to 23.1 %).	GC and GC-MS	30
Kutching	α pinene (2.3 to 5.4%), sabinene (6.7 to 13.3%), limonene (14.5 to 17.5%), β caryophyllene (20.8 to 39.1%).	GC and GC-MS	30

Different Extraction Methods of Black Pepper (Specially Piperine): Piperine, the natural bio-enhancer, a bio-active component of black pepper, has various pharmacological properties. It is extremely effective against pests. Therefore, in our study, we are trying to summarize various extraction methods of piperine from black pepper (listed in **Table 2**). Traditional extraction procedures comprise maceration, Soxhlet extraction, and soaking. These methods require a large amount of solvent, time-consuming, high temperature, tedious and low extraction yield. However, modern extraction technologies have the potential to overcome all these drawbacks. After extraction, identification of piperine is a crucial step (listed in **Table 3**).

Sequential Microwave-Ultrasound-Assisted Extraction: Gorgani *et. al*., [31] reported a piperine extraction procedure using Sequential Microwave-Ultrasound. In this method, black pepper powder of 0.5 g (particle size- 0.15 mm) mixed with a solvent (ethanol) ratio of 20:1 and produced 46.6 mg piperine. During this procedure, the temperature of the ultrasound was 50 °C for 30 min and 100 W microwave powers for 1 min. Purity was 81.4% of the isolated piperine and analyzed by HPLC technique. To obtain a higher yield at optimized conditions, this extraction is a combination of microwave-assisted extraction (MAE) and ultrasound-assisted extraction (UAE).

Piperine Extraction with Various Solvents: Shingate *et. al*., [32] and Tripathi [33] reported various solvents as a novel technique for piperine extraction. Shingate *et al*., [32] used ethanol, glacial acetic acid and dichloromethane as solvents. Several classical methods such as Soxhlet extraction (ethanol), refluxed extraction (dichloromethane), cold maceration (glacial acetic acid) were applied for isolation and purification procedure. Whereas comparing with other solvents, maceration with glacial acetic acid proved the best solvent with high extraction and purity. Tripathi [33,] in his study, also used three solvents. Those were ethanol, propionic acid, and dichloromethane. Except for propionic acid, ethanol and dichloromethane were the same as used by Shingate *et al*. [32]. This study also followed a classical method of extraction such as Soxhlet extraction (ethanol), round bottom flask condensation (dichloromethane), cold maceration (propionic acid). The highest yield and purity were obtained from propionic acid extraction. HPLC, FT-IR, TLC, UV-visible spectrophotometer, *etc.* analytical methods were used for compound identification in both cases.

Parametric Optimization of Microwave Reflux Extraction: Olalere *et al*., [34] described another method for piperine extraction. This method was a combination of both the traditional and classical methods with high extraction, higher selectivity, and small solvent usage. Microwave reflux extraction with Taguchi L9-orthogonal design was employed for the isolation process.

This method was improved by maceration, Soxhlet extraction, cold percolation, hydro-distillation, hydrotropic solubilization. 5 g of white (particle size - 0.105 mm) was mixed solvent (distilled water) and stirred properly. During microwave reflux extraction, irradiation time was 90 min at 300 W microwave power 4.278 (v/w) % yields were obtained through this process. Functional groups were identified by scanning electron microscopy (SEM) and Fourier transform infrared analysis (FTIR).

Extraction of Piperine with Surfactant, Hydrotrope, and Mix of Surfactant + Hydrotrope: Yu *et. al*., [35] reported surfactants assisted extraction of piperine. It was an orthogonal, single-factor process. Surfactants, as well as an enzyme, also took part in this experiment. 10 g Black pepper powder (less than 10 mesh size), neutral protease, cellulose and water were mixed in a round bottom flask for 4 hours at 60 °C. HPLC, UV-spectroscopy were used for the measurement of extracted piperine. Under optimized extraction conditions, 4.42% (HPLC) piperine was obtained. Raman and Gaikar [18] used hydrotrope molecules for improved extraction of piperine. Primarily it enters the cellular structures and then permeabilizes the cell. Obtained piperine was all free from oleoresins, and purity was ~90%. 10 g of black pepper powder (50 µm particle size) was added with hydrotrope molecule (sodium alkylbenzene sulfonates and sodium butyl monoglycol sulfate) and agitated at 1100 rpm for 2 hours at 30 °C.

The solution was filtered and piperine was obtained after 1 h. Padalkar and Gaikar [36] reported the combined effect of surfactant and hydrotrope in their study for piperine extraction. In this experiment, butyl benzene sulfonate was used as a hydrotrope and sodium dodecyl sulfate (SDS) as a surfactant. Results showed that the piperine crystals from surfactant + hydrotrope were much clearer than organic solvents.

Microwave Reflux Method: Olalere *et al*., [37] described a microwave-based multi-level Taguchi procedure for the extraction of black pepper. Suitable conditions for the best results were - 25 g of black pepper powder (0.105 mm particle size) mixed with optimum quantity of water, microwave power at 350 W, irradiation time 120 min, 12 g/ml molar ratio. 5.64% yield was obtained. SEM and FTIR were used for further characterization.

Enzyme-Assisted Supercritical Carbon Dioxide Extraction of Black Pepper: Dutta and Bhattacharjee [38] reported enhanced extraction of black pepper through enzyme-assisted supercritical carbon dioxide (SC-CO_2). This reaction was conducted with a-amylase. Suitable conditions for the extraction were 20 g of black pepper (particle diameter - 0.42 ± 0.02 mm), CO_2 flow rate - 2 L/min, 300 bar, and 600 °C. Enzyme activity increases the yield by 2.13 times.

Effects of Microwave Heating: The study of Olalere *et al*., [39] depicted that yield of 48.22 mg/g from black pepper could be procured under suitable conditions. In this reaction, water was the solvent within which 25 g of black pepper powder was added. The feed-solvent ratio was 1:12. The time required for extraction was 80 min. The results showed a trade-off between high microwave power and irradiation time.

Accelerated Solvent Extraction (ASE): Ahmad *et al*., [40] reported a quick, cost-effective, and consistent extraction technique of piperine extraction from black pepper. DCM (Dichloromethane) n-hexane and methanol were used as solvents, respectively. However, DCM proved to be the best-extracting media at 70 °C, 100 atm, and 10 min of extraction time. 93.89% yield was obtained using DCM. This study first reported the use of UHPLC-DAD along with ASE for identification and quantification. The combined effect of ASE-UHPLC-DAD helps easy detection of adulteration of commercial foodstuff.

Double Bypasses Soxhlet Apparatus: Subramanian *et al*., [41] described a rapid, simple, and economical extraction method which was a modified version of the traditional Soxhlet extraction process. In this experiment, methanol is used as extracting solvent because it has maximum solubilizing capacity. Preferable conditions for the extraction were 8 ± 1.00 min, 12 ± 1 h and 3.90 ± 0.10 g. In this experiment, both the time and amount of solvent were half as compared to the Soxhlet apparatus with the same yield. Hence this method is one of the most appropriate for piperine extraction from black pepper.

Pest Management Using Black Pepper: Black pepper has been a prosperous source of bioactive compounds from ancient times. These bioactive compounds are not only useful as medicine but also as natural pesticides.

Pest management system using plant-derived pesticides helps to reduce the load of chemicals. Different plant parts are used for different types of remedies.

Leaves, stem, root, fruit, secondary components or essential oil, *etc.* could be used as pest repellent [54]. This review paper tried to summarize various pest control measures using black pepper with special importance to piperine.

TABLE 2: VARIOUS EXTRACTION PROCESSES IN TABULAR FORM:

Sl. no.	Extraction Method	Solvent used	Extraction time	Yield	Pros	Reference
1	Sequential Microwave-Ultrasound-Assisted Extraction	Ethanol, methanol, acetone, dichloromethane	1 min-microwave 30 min-ultrasound temperature	46.6 mg	Better extraction yield than microwave-assisted, Soxhlet, ultrasound-assisted extraction.	31
2	Reflux microwave extraction	Water	90 min	4.278 %	Time-efficient, high yield and selectivity, little amount of solvent	34
3	Soxhlet, refluxed, cold maceration	Ethanol, propionic acid and dichloromethane.	2hours, 25 min and unknown.	3.2%, 5% and 4.6% respectively	Most effective solvent was propionic acid.	33
4	Soxhlet, refluxed, cold maceration	Ethanol, glacial acetic acid and dichloromethane	2hours, 20 min and unknown	3.2%, 5% and 4.6% respectively	Glacial Acetic Acid was the most effective one.	32
5	Surfactant-assisted enzymatic extraction	Surfactant- sodium stearoyl lactylate	4hours	4.54%	Better than soxhlet, ultrasonic-assisted, microwave-assisted and supercritical carbon dioxide extraction.	35
6	Hydrotropic solubilization	Sodium alkyl benzene sulfonates and sodium butyl monoglycol sulfate	2hours	~90% pure and oleoresin free	Pure and fast extraction.	19
7	Solubility extraction	Surfactant- (SDS) hydrotrope-butyl benzene sulfonate	---------	----------	Obtained piperine was purer and clearer.	36
8	Microwave reflux pulsed extraction	Water	90 min	5.64 w/w	Fast extraction process	42
9	Enzyme-assisted supercritical carbon dioxide	Solvent free reaction	2.25hours and 4.25 h	1.36 ± 0.04e	Fast and continuous mode of extraction	38
10	Microwave reflux extraction	Water	80 min	48.22 mg/g	Extractions with high quality	39
11	Accelerated solvent extraction (ASE)	Dichloromethane (best) n- hexane, DCM and methanol	10 min	93.89%	Simple, fast, sensitive, sustainable and effective	40
12	Double bypasses soxhlet extraction	Methanol	12hours	3.90%	Modified version of soxhlet extraction with less time and solvent	41
13	Micellar Extraction	[C12betaine] Cl in water	3hours	3.74 wt.-%	Recycling of solvent for 5 times with same extraction efficiency	43
14	Microwave reflux extraction	Water	90 min	2.0586 w/w%	High selectivity and quality due to combined effect of microwave and soxhlet	44
15	Soxhlet	Ethanol	---------	2.9%	Novel, easy and effective extraction of piperine for API drug at large scale.	45
16	Reflux microwave extractor	Water	90 min	2.056 (W/W)	Better than hydrodistillation method.	46

17	Supercritical fluid extraction (SCF)	SCCO2 co-solvent: ethanol	60 min	SCO+ethanol-184.7%	Fast and effective extraction with less time and solvent	47
18	Soxhlet	Ethanol	3hours	1%w/w	Fast and simple method and used in quality control	48
19	Water-bath reflux	Chloroform, ethyl acetate, ethanol (best), methanol and water	4hours	ethanol-3.78%	Solvents with decreasing order of polarity produces highest yield.	49
20	Ultrasonic-microwave assisted extraction (UMAE), microwave assisted extraction (MAE) and ultrasonic assisted extraction (UAE)	Solvent free	7 min	4.0 ± 0.1%	UMAE is the best among others and green technique for extraction	50

TABLE 3: SEPARATION AND IDENTIFICATION OF PIPERINE (MAJOR COMPONENT OF BLACK PEPPER)

Extraction Metho	Separation process	Identification	Reference
Reflux extraction	With cold solution of NaOH	By comparison of spectroscopic (FTIR,MS and NMR) and physical data (MP =128°C)	51
Reflux extraction	TLC	UV light	8
Maceration with methanol	TLC	HPLC, 1H and 13C NMR	52
Maceration	Column chromatography and TLC	HPLC, GC-MS	53

Larvicidal Effects: Sarapothong *et. al.*, [11] reported that both black pepper (*Piper nigrum* L.) and piperine had larvicidal effects against different strains of *Anopheles* larvae. Ground black pepper and piperine were fed to the larvae in different quantity and the mortality rates were checked after 24 h and 48 h, respectively. Results show black pepper was more effective than piperine for strains of *Anopheles* larvae. Another report also demonstrated the larvicidal effect of black pepper against different strains of dengue fever mosquito, *Aedes aegypti* [55]. Ethanolic extraction of black pepper powder with a lethal concentration of 0.405 ppm was recorded for the mortality of the larvae within 24 h. Diamondback moth larvae were also effectively controlled by black pepper application 11. Methanolic extract of black pepper caused 100 % mortality of moth larvae at a 5.0 mg/ml concentration rate.

Insecticidal Effects: Among various plant-based insecticides, the use of black pepper is a well-identified phenomenon. Toxic effects of methanolic extract of *Piper nigrum* against *Anopheles gambiae* had been reported. LC_{50} value was 27 ppm and mortality was registered after 24 h. Insecticidal properties against *Spodoptera litura* [56], *Sitophilus oryzae* L. and *Corcyra cephalonica* (St.) 8, Colorado potato beetle [57], pulse beetle [58] was also reported. Potential natural pesticides procured from black pepper extract also act as egg hatchability regulator, adult emergence regulator antifeedant and growth inhibitor [59]. Piperine reduces the hatchability of eggs of *Spodoptera frugiperda* and *Diatraea saccharalis*. It also tested for phytotoxicity on different vegetables and showed a positive impact on seed germination [25].

Acaricidal Effects: Park *et. al.*, [6] showed in their study that pipernonaline extracted from *Piper longum* L. had acaricidal activity against *Tetranychus urticae*. Although the mode of action of black pepper as acaricide still needs further investigation.

Another report of black pepper isolation demonstrated acaricidal effect against African Red Mite [60]. This study showed that the mortality rate of mites were 96% and 92% at LC_{50} value 0.34 and 0.54%, respectively.

Aphicidal Effects: Black pepper has excellent aphicidal properties. It shows its activity against mustard aphid [61], green peach aphid (Myzus persicae) [62], *Brevicoryne brassicae* L *and Aphis craccivora* Koch [63]. Ahmed *et al*. [62] reported that the black pepper extracts applied on the green peach aphids in a contact depended on the manner and it showed 80% efficacy against those aphids. Furthermore, synergistic effects of black pepper with other plant extracts could increase this efficacy up to 98.33%.

TABLE 4: PESTICIDAL EFFECT OF BLACK PEPPER:

S. no.	Mode of action	Major component	Target pest	Dosage	Exposer time	Referene
1	Larvicidal	Ground black pepper and piperine	Strains of Anopheles larvae	50 mg of treatment mixture	24 h and 48 h, respectively	12
2	Insecticidal	Limonene, α and β pinene and caryophyllene	*Sitophilus oryzae* L. and *Corcyra cephalonica* (St.)	LC50 values- 287.7 µL/L and 530.5 µL/L respectively	72 h	8
3	Ant repellent	Black pepper	*Tapinoma sessile* (odorous house ant)	LC50 – 15 LC99-41	3 h	13
4	Insecticidal	Black pepper	*Sitophilus zeamais* adults	Fumigant -0.152 Contact -0.126	48 h	4
5	Insecticidal	Black pepper	*Sitaphitus orywe* (L.) and *Callosobruchus maculatus* (F.)	Adult *S. orywe* crud-3.4 µg/insect purified-4.8 µg/insect adult *C. maculatus* crud- 4.5 µg/insect purified -7.2 µg/insect	24 h	9
6	Larvicidal	Piperine	Diamondback moth, *Plutella xylostella*,	The LC50 value of piperine was >0.5 mg/mL.	48 h	11
7	Insecticidal and acaricidal	Pipernonaline and piperoctadecalidine	arthropod pests	Pipernonaline (LD50=125 mg/l) piperoctadecalidine (LD50=95.5 mg/l)	-----------	7
8	Larvicidal	Piperolein B and piperchabamide D	Diamondback moth	Piperolein B-2 µg/mL piperchabamide D-0.95 µg/mL	96 h	64
9	Physiological and biochemical	Black pepper leaves	*Aedes aegypti*	LC50=34.97	3 h	65
10	Acaricidal	Black pepper	African red mite	LC50- 0.54% at 92% mite mortality	24 h	60
11	Insecticidal	*Piper nigrum*	*Megalurothrips sjostedti*	0.01%, 0.1%, and 1% concentration	5 and 10 min	66
12	Aphicide	Black pepper	*Myzus persicae*	5%	24 h	62

RESULTS AND DISCUSSION: This review paper compiled the extraction process of natural products and their effectiveness as bio-pesticides. In the case of extraction processes, different methods, time, temperature, pressure, particle size, solvents, solubility, and solvent to solid ratio are plays a significant role. It has been evident that the traditional extraction process such as Soxhlet extraction takes 24 h, while double bypasses. Soxhlet apparatus takes only 12 h. Microwave extraction techniques are rapid methods with only 7 min of extraction time. This extraction is sometimes assisted with ultrasonic or reflux extraction and makes it more efficient. Another method, enzyme-assisted supercritical carbon dioxide takes merely 2.5 h. Considering solvents with different polarities were tested for the effective extraction of black pepper, such as chloroform, ethyl acetate, ethanol (best), methanol, water, propionic acid (higher yield and in higher purity), dichloromethane, *etc.* were used. Solvent-free or green extractions are also very popular phenomenon to prevent solvent loss. Particle size also varies according to the extraction method. Sometimes it ranges from 16 mesh size to 160 mesh size or a few µm to mm. Excessive heat in the continuous extraction process is immense trouble for thermolabile components. Pulse extraction with simultaneous heating and cooling process helps to retain a lower temperature. A wide range of factors is also controlling the effectiveness of isolated components derived for pest mitigation. Among them, lethal concentration, dose, time of exposure, target organism, life stage of the insect, and mortality rate are important factors. The time of exposure varies from few hours to 72 h or even 96 h depending on the organism and its growth stage. The same thing happens in the case of mortality. Most of the cases reported 100% mortality, although it may be 90% or 95% in some cases.

Piperine is one of the most potent bioactive components of black pepper, which acts as a natural pesticide. It is highly effective on newly hatched eggs, has antifeedant activity against insect pests, acts as an insecticide. However, the study of phytotoxicity and allelopathic effects of any potent natural pesticides are significant tests for its vivid application. Effects of piperine on vegetable seeds germination were tested, and no adverse effects were reported. Despite the successful utilization of black pepper as a potent natural pesticide, there is still ambiguity in the mode of action of piperine. Applications of bio-pesticides are dose-dependent manner. So, the correct value of lethal dose or concentration is a crucial step. Hence, during natural pesticide formulation and application, all the vital factors should be considered.

CONCLUSION: Among various extraction processes of *Piper nigrum* L., microwave-assisted extraction has proven its effectiveness. It is rapid, less labor-intensive, requires less usage of solvent, and, most importantly, cost-effective. Comprehensively, the study shows that the extraction rate of bioactive components is increasing with the increasing rate of pressure, temperature and solvent flow rate. Remarkably there is a trade-off between particle size of black pepper and rate of extraction up to a certain extent. The smaller size of particles is responsible for improved outcomes. In continuous extraction processes, excessive temperature may damage the bioactive components. Purity of the bioactive components is largely reliant on the type of extraction solvents. The decreasing polarity of solvents provides better quality of extracted components. Solvent-free extractions are a new method. Natural pesticides from black pepper extract act as larvicidal, acaricidal, insecticidal, aphicidal, and also cause feeding deterrence of pests. Pest repellency and effectiveness of natural insecticides depend on two main parameters, *i.e.*, concentration rate and exposure duration. Occasionally, the addition of surfactants to black pepper extraction processes surges its efficacy. The rate of proficiency and effectiveness of natural pesticides fluctuates as the life cycle stages of the target organism change. To discover the broad-spectrum effectiveness of plant-derived pesticides, further studies on each component's structure, intensity, and mode of action at different life cycle stages of the pest population will be necessary.

ACKNOWLEDGMENT: This study was supported by a research fellowship to the first author by the Swami Vivekananda Merit-cum-Mean Scholarship and the University of North Bengal.

CONFLICTS OF INTEREST: The authors declare that they have no conflict of interest.

REFERENCES:

1. Epstein Willium W, Netz David F and Seidel Jimmy L: Isolation of piperine from black pepper. Journal of Chemical Education 1993; 70: 598-99.
2. Scott IM, Jensen HR, Philogène BJR and Arnason JT: A review of *Piper spp*. (*Piperaceae)* phytochemistry, insecticidal activity and mode of action. Phytochemistry Reviews 2008; 7: 65-75.
3. Kumar Chaubey M: Evaluation of insecticidal properties of *Cuminum cyminum* and *piper nigrum* essential oils against sitophilus zeamais. Journal of Entomology 2017; 14: 148-54.
4. Hussein AE, Abd Elhaseeb H, Mohamed RA, Abdel-Mogib M and Abou Elnaga Z: Toxicity of three chemical extracts of black pepper fruits against two stored grain insect pests. Int J Pharm Sci Invent 2017; 6: 20-28.
5. Ashouri Shabnam and Sahyesteh N: Insecticidal activities of two powdered spices, black pepper and red pepper on adults of *Rhyzopertha dominica* (F.) and *Sitophilus granarius* L. Mun Ent Zool 2010; 5: 600-07.
6. Park Byeoung-Soo, Lee Sung-Eun, Choi Won-Sik, Jeong Chang-Yoon, Song Cheol and Cho Kwang-Yun: Insecticidal and acaricidal activity of pipernonaline and piperoctadecalidine derived from dried fruits of *Piper longum* L. Crop Protection 2002; 21: 249-51.
7. Khani M, Awang R Muhamad and Omar D: Insecticidal effects of peppermint and black pepper essential oils against rice weevil, *Sitophilus oryzae* L. and rice moth, *Corcyra cephalonica*st. Journal of Medicinal Plants 2012; 11(43): 97-110.
8. Su Helen CF: Insecticidal properties of black *Pepper* to rice weevils and cowpea weevils. Journal of Economic Entomology 1977; 70: 18-21.
9. Su Helen CF and Horva Robert: Isolation, identification, and insecticidal properties of *Piper nigrum* amides. J Agric Food Chem 1981; 29: 115-18.
10. Park I: Larvicidal activity of constituents identified in *piper nigrum* L. fruit against the diamondback moth, *Plutella xylostella*. Kor J of Applied Ent 2012; 51: 149-52.
11. Samuel M, Oliver SV, Coetzee M and Brooke BD: The larvicidal effects of black pepper (*Piper nigrum* L. and piperine against insecticide resistant and susceptible strains

of anopheles malaria vector mosquitoes. Parasit Vectors 2016; 9(238): 1-9.

12. Mutalib Nurliana Abd, Azis Tun Mohd Firdaus, Mohamad Sarina, Azizan Nur Izzati, Sidek Hamidah Jaafar, H Roziana M and Razali Zainab: The repellent and lethal effects of black pepper (*Piper nigrum*), chilli pepper (*Capsicum annuum*) and cinnamon (*Cinnamomum zeylanicum*) extracts towards the odorous house ant. ARPN J Eng Appl Sci 2017; 12(8): 2710-14.
13. Takooree Heerasing, Aumeeruddy Muhammad Z, Rengasamy Kannan RR, Venugopala Katharigatta N, Jeewon Rajesh, Zengin Gokhan and Mahoomodally Mohamad F: A systematic review on black pepper (*Piper nigrum* L. from folk uses to pharmacological applications. Crit Rev Food Sci Nutr 2019; 59: 1-34.
14. Ravindran PN and Kallupurackal JA: Black *Pepper*. Handbook of herbs and spices. Wood Head Publishing Limited Second Edition 2012.
15. Srivastava AK and Singh VK: Biological action of *Piper nigrum* - the king of spices. EJBR 2017; 7: 223-33.
16. Tran Thien Hien, Ha Le Ke, Nguyen Duy Chinh, Dao Tan Phat, Nhan Le Thi Hong, Nguyen Dai, Nguyen Trinh Duy, Vo Dai-Viet N, Tran Quoc Toan and Bach Long Giang: The study on extraction process and analysis of components in essential oils of black pepper (*Piper nigrum* L.) seeds harvested in gia lai province, vietnam. Processes 2019; 7: 1-15.
17. Meghwal Murlidhar and Goswami TK: Nutritional, medicinal and functional properties of black *Pepper*: a review. J Nutr Food Sci 2012; 01(2): 1-5.
18. Raman G and Gaikar VG: Extraction of piperine from *piper nigrum* (Black *Pepper*) by hydrotropic solubilization. Ind Eng Chem Res 2002; 41: 2966-76.
19. Raman G and Gaikar VG: Microwave-assisted extraction of piperine from *Piper nigrum*. Ind Eng Chem Res 2002; 41: 2521-28.
20. Souto RNP, Harada AY, Andrade EHA and Maia JGS: Insecticidal activity of piper essential oils from the amazon against the fire ant *Solenopsis saevissima* (smith) (*Hymenoptera*: formicidae). neotrop. Entomol 2012; 41: 510-17.
21. Kapoor IPS, Singh Bandana, Singh Gurdip, De Heluani Carola S, De Lampasona MP and Catalan Cesar AN: Chemistry and *in-vitro* antioxidant activity of volatile oil and oleoresins of black pepper (*Piper nigrum*). J Agric Food Chem 2009; 57(12): 5358-64.
22. Bakkali F, Averbeck S, Averbeck D and Idaomar M: Biological effects of essential oils - A review. Food Chem Toxicol 2008; 46: 446-75.
23. Nile SH, Nile AS, Keum YS, Baskar V and Ramalingam S: *In-vitro* and in planta nematicidal activity of black pepper (*Piper nigrum* L.) leaf extracts. Crop Prot 2017; 100: 1-7.
24. Tavares WS, Cruz I, Petacci F, Freitas SS, Serrão JE and Zanuncio JC: Insecticide activity of piperine : toxicity to eggs of *Spodoptera frugiperda* (*Lepidoptera*: noctuidae) and *Diatraea saccharalis* (*Lepidoptera*: pyralidae) and phytotoxicity on several vegetables. Journal of Medicinal Plant Research 2011; 5: 5301-06.
25. Damanhouri Zoheir A and Ahmad Aftab: A review on therapeutic potential of *Piper nigrum* L. (black pepper): the king of spices. Med & Aromatic Plants 2014; 03: 1-6.
26. Menon AN and Padmakumari KP: Essential oil composition of four major cultivars of black pepper (*Piper nigrum* L.)-IV. J Essent Oil Res 2003; 15(3): 155-57.
27. Menon AN, Padmakumari KP and Jayalekshmy A: Essential oil composition of four major cultivars of black pepper (*Piper nigrum* L.) III. J Essent Oil Res 2000; 12(4): 431-34.
28. Menon AN, Padmakumari KP and Jayalekshmy AJ: Essential oil composition of four major cultivars of black pepper (*Piper nigrum* L.). J Essent Oil Res 2002; 14: 84-86.
29. Gopalakrishnan M, Menon AN, Padmakumari KP, Jayalekshmy A and Narayanan CS: GC analysis and odor profiles of four new Indian genotypes of *Piper nigrum* L. J Essent Oil Res 1993; 5: 247-53.
30. Menon AN and Padmakumari KP: Studies on essential oil composition of cultivars of black pepper (*Piper nigrum* L.)-V. J Essent Oil Res 2005; 17(2): 153-55.
31. Gorgani L, Mohammadi M, Najafpour GD and Nikzad M: Sequential microwave-ultrasound-assisted extraction for isolation of piperine from black pepper (*Piper nigrum* L.) Food Bioprocess Technol 2017; 10: 2199-07.
32. Shingate PN, Dongre PP and Kannur DM: New method development for extraction and isolation of piperine. IJPSR 2013; 4: 3165-70.
33. Tripathi AK: novel methodology for the isolation of pure piperine from plant source through. J Chem Educ Res Pract 2017; 1: 1-5.
34. Olalere OA, Abdurahman NH, Alara OR and Habeeb OA: Parametric optimization of microwave reflux extraction of spice oleoresin from white pepper (*Piper nigrum*). J Anal Sci Technol 2017; 8: 1-7.
35. Yu Yang, Hu Siqi, Fu Duojiao, Zhang Xiaoxu, Liu Hongqin, Xu Baocai and Huang Mingquan: Surfactant-assisted enzymatic extraction of piperine from *Piper nigrum* L. Int J Food Prop 2020; 23: 52-62.
36. Padalkar K. V. and Gaikar V. G.: Extraction of piperine from *piper nigrum* (black pepper) by aqueous solutions of surfactant and surfactant + hydrotrope mixtures. Sep Sci Technol 2008; 43: 3097-18.
37. Abayomi O, Nour O, Abdurahman H and Ruth O: Extraction, radical scavenging activities and physicochemical fingerprints of black pepper (*Piper nigrum*) extract. J Food Meas Charact 2017; 11: 2195-01.
38. Dutta S and Bhattacharjee P: Enzyme-assisted supercritical carbon dioxide extraction of black pepper oleoresin for enhanced yield of piperine-rich extract. J Biosci Bioeng 2015; 120: 17-23.
39. Olalere OA, Abdurahman NH and Yunus M: The effects of microwave heating on the extraction yield and elemental composition of black and white pepper (*Piper nigrum*) extracts. J Chem Eng Ind Biotechnol 2017; 2: 59-67.
40. Ahmad R, Ahmad N and Shehzad A: Solvent and temperature effects of accelerated solvent extraction (ASE) with Ultra-high pressure liquid chromatography (UHPLC-PDA) technique for determination of Piperine and its ICP-MS analysis. Ind Crop Prod 2019; 136: 37-49.
41. Subramanian R, Subbramaniyan P, Noorul Ameen J and Raj V: Double bypasses soxhlet apparatus for extraction of piperine from *Piper nigrum*. Arab. J Chem 2016; 9(1): S537-S40.
42. Abayomi O, Hamid N, Yunus M, Ruth O and Akbari S: Evaluation of optimization parameters in microwave reflux extraction of piperine-oleoresin from black pepper (*Piper nigrum).* beni-suef univ. J Basic Appl Sci 2018; 7: 626-31.
43. Ressmanna Anna K, Zirbsb Ronald, Presslera Martin, Gaertnera Peter and Bica Katharina: Surface-active ionic liquids for micellar extraction of piperine from black pepper z. Naturforsch 2013; 68(10): 1129-37.
44. Abayomi OO, Nour AH, Ruth AO and Habeeb OA: Optimized microwave reflux extraction and antioxidant

activities of piperine from black and white *Piper nigrum*. Chem Eng Res Bull 2017; 19: 139-44.
45. Khan Zihan Rahman, Moni Fatema, Sharmin Suriya, Al-Mansur Muhammad Abdullah, Gafur Abdul, Rahman Obaidur and Afroz Farhana: Isolation of bulk amount of piperine as active pharmaceutical ingredient (api) from black pepper and white pepper (*Piper nigrum*.). Pharmacol. Pharm 2017; 8: 253-62.
46. Resources N and Razak LT: Comparative study of pulsed microwave and hydro distillation extraction of piperine oil from black pepper. IIUM Eng J 2017; 18: 87-93.
47. Nagavekar N: Enhanced extraction of oleoresin from *Piper nigrum* by supercritical carbon dioxide using ethanol as a co-solvent and its bioactivity profile. Food Process Eng 2017; 41: 1-12.
48. Kolhe SR, Borole P and Patel U: Extraction and evaluation of piperine from *Piper nigrum* Linn. IJABPT 2011; 2: 144-49.
49. Zarai Z, Boujelbene E, Salem N Ben, Gargouri Y and Sayari A: Antioxidant and antimicrobial activities of various solvent extracts, piperine and piperic acid from *Piper nigrum*. LWT - Food Sci Technol 2013; 50(2): 634-41.
50. Wang Ying, Li Rong, Jiang Zi-Tao, Tan Jin, Tang Shu-Hua, Li Ting-Ting, Liang Lu-Lu, He Hai-Jun, Liu Yu-Miao, Li Jiu-Tian and Zhang Xing-Cheng: Green and solvent-free simultaneous ultrasonic-microwave assisted extraction of essential oil from white and black peppers. Ind Crop Prod 2018; 114: 164-72.
51. Tavares WS, Cruz I, Petacci F, Freitas SS, Serrão JE and Zanuncio JC: Insecticide activity of piperine: Toxicity to eggs of *Spodoptera frugiperda* (*Lepidoptera*: noctuidae) and *Diatraea saccharalis* (*Lepidoptera*: pyralidae) and phytotoxicity on several vegetables. J Med Plant Res 2011; 5: 5301-06.
52. Park IK, Lee SG, Shin SC, Park JD and Ahn YJ: Larvicidal activity of isobutyl amides identified in *Piper nigrum* fruits against three mosquito species. J Agric Food Chem 2002; 50: 1866-70.
53. Kitayama Takashi, Yasuda Kanako, Kihara Takeharu, Ito Michiho, Fukumoto Hiromi and Morimoto Masanori: *Piperine analogs* in a hydrophobic fraction from *Piper ribersoides* (Piperaceae) and its insect antifeedant activity. Appl Entomol Zool 2013; 48: 455-59.
54. Abdallah EM: Black pepper fruit (*Piper nigrum* L.) as antibacterial agent: A mini-review. J Bacteriol Mycol 2018; 6: 141-45.
55. Kumar S, Warikoo R and Wahab N: Larvicidal potential of ethanolic extracts of dried fruits of three species of peppercorns against different instars of an Indian strain of dengue fever mosquito, *Aedes aegypt*i L. *Diptera culicidae* parasitel. Res 2010; 107: 901-07.
56. Fan Loh Siew, Muhamad R, Omar D and Rahmani M: Insecticidal properties of *Piper nigrum* fruit extracts and essential oils against *Spodoptera litura*. Int J Agric Biol 2011; 13: 517-22.
57. Scott IM, Jensen H, Scott JG, Isman MB, Arnason JT and Philogène BJR: Botanical insecticides for controlling agricultural pests: piperamides and the *Colorado potato* beetle *Leptinotarsa decemlineata* say (*Coleoptera*: chrysomelidae. Arch Insect Biochem Physiol 2003; 54: 212-25.
58. Swamy SVSG and Raja DS: Use of black pepper and clove against pulse beetle *Callosobruchus maculatus* (F.) in green gram. Indian J Entomol 2018; 80(4): 1291-95.
59. Khani M, Awang RM, Omar D and Rahmani M: Toxicity, antifeedant, egg hatchability and adult emergence effect of *Piper nigrum* L. and *Jatropha curcas* L. extracts against rice moth, *Corcyra cephalonica* (Stainton). J Med Plants Res 2013; 7: 1255-62.
60. Sarapothong K, Pumnuan J and Insung A: Acaricidal toxicity of nano essential oil of black pepper against african red mite (*Eutetranychus africanus* (Tucker)). Int J Agric Technol 2017; 13: 2267-74.
61. Gupta M, Gupta A and Gupta S: Insecticidal activity of essential oils obtained from *Piper nigrum* and *Psoralea corylifolia* seeds against agricultural pests. Asian J Res Chem 2013; 6: 360-63.
62. Ahmed Qasim, Agarwal Manjree, Al-Obaidi Ruaa, Wang P and Ren Y: Evaluation of aphicidal effect of essential oils and their synergistic effect against *Myzus persicae* (sulzer) (Hemiptera: aphididae). Molecules 2021; 26: 1-19.
63. Abdu-allah G: Aphicidal activity of imidacloprid and primicarb compared with certain plant extracts on *Brevicoryne brassicae* L and *Aphis craccivora* koch. Assiut J Agric Sci 1997; 43: 104-14.
64. Hwang KS, Kim YK, Park KW and Kim YT: Piperolein B and *Piper chabamide* D isolated from black pepper (*Piper nigrum* L.) as larvicidal compounds against the diamondback moth (*Plutella xylostella*). Pest Manag Sci 2017; 73: 1564-67.
65. Lija-Escaline Jalasteen, Senthil-Nathan Sengottayan, Thanigaivel Annamalai, Pradeepa Venkatraman, Vasantha-Srinivasan Prabhakaran, Ponsankar Athirstam, Edwin Edward Sam, Selin-Rani Selvaraj and Abdel-Megeed Ahmed: Physiological and biochemical effects of botanical extract from *Piper nigrum* Linn (Piperaceae) against the dengue vector aedes aegypti liston Diptera culicidae parasitol. Res 2015; 114(11): 4239-49.
66. Abtew A, Subramanian S, Cheseto X and Kreiter S: Repellency of plant extracts against the legume flower thrips *Megalurothrips sjostedti* Thysanoptera: Thripidae. Insects 2015; 6: 608-25.

How to cite this article:
Sinha and Ray: Scope of Black Pepper *Piper nigrum* L. extract in pest control. Int J Pharmacognosy 2021; 8(9): 351-60. doi link: http://dx.doi.org/10.13040/IJPSR.0975-8232.IJP.8(9).351-60.