Meta-heuristic Optimization Algorithms for Irradiated Fruits and Vegetable Image Detection

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Abstract: - Despite the food irradiation benefits, it isn't accepted. Food irradiation is the process that exposed food to ionization radiation, such as electron beams, X-rays , or gamma radiation to inactivate food spoilage organisms. This paper discusses the effect of radiation on the food images, how the food changes before and after taking the radiation dose, and how the PSNR (Peak Signal to Noise Ratio) changes using different metaheuristic optimization algorithms. In this paper, Image Segmentation is based on three different metaheuristic algorithms used to detect the difference between before and after irradiation. The three algorithms are (1) PSO (Particle Swarm Optimization), DPSO (Darwinian PSO), and FO-DPSO (Fractional-Order DPSO), (2) CS (Cuckoo Search), and (3) SFLA (Shuffled Frog Leaping Algorithm). The algorithms succeeded in discovering the effect of radiation on Green Apple, Cucumber, and Orange even if it is not visually recognized. Also, the histogram of the image shows the difference between before and after irradiation.

Key-Words: - Irradiation Food, Particle Swarm Optimization , Cuckoo Search, Shuffled Frog Leaping Algorithm , Meta-heuristic

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1 Introduction

Radiation is the emission of energy that can travel through space. Radiation cannot be detected by the human senses because it has no smell or sound and invisible [1]. It divided into two categories: ionizing and non-ionizing radiation . Ionizing radiation has enough energy to release electrons from an atom, and that way leaving the atom charged . Non-ionizing radiation, such as radio waves, ultra-violet radiation [2]. Ionizing radiation can cause chemical changes by breaking chemical bonds, damage to matter, such as living tissue. It is necessary to control the exposure time because it is dangerous at high levels [3].

Food irradiation is a processing technique that exposed food to a source of ionizing radiation , such as electron beams, X-rays , or gamma radiation to preserve food and inactivate food spoilage organisms, including bacteria, and yeasts [3, 4]. It kills without heat the harmful bacteria because of this the food irradiation process can be called a cold pasteurization. It's effective in the extension of shelf-life of fresh fruits and vegetables by controlling the normal biological changes that can delay fruit ripening , or prevents vegetables from sprouting [5]. Radiation can delay the ripening of green bananas , prevent the greening of white potatoes , inhibit the sprouting of potatoes, destroy disease-causing organisms , like parasitic worms and insect pests, that damage food in storage , soften legumes to shorten the cooking time, and increase the yield of juice from grapes [6]. But, not all foods are appropriate for irradiation. There are some fruits are sensitive to radiation, such as cucumbers, grapes, and some tomatoes. The amount of radiation absorbed by the food during the exposure time called "dose ". The dose controlled by two factors: time the food exposed to the source and intensity of the radiation. The irradiation is measured by unit called "gray (Gy)" that refers to the absorbed dose. In [3], a food nondestructive irradiation detection method is proposed. The experiments are done on apple images before and after different doses of gamma rays. Statistical calculation and Zernike moments are two methods used for extracting the color changes and converting them into features vectors. These methods are cheap and simple and they overcome the disadvantages of other methods that are complex and very costly.

The objective of this paper is to discuss the effect of radiation on the food images, how the food changes before and after taking radiation dose by measuring the PSNR. The experiments are done on Green Apple, Cucumber, and Orange that exposed to radiation dose 1 KGray. Image Segmentation based on three different metaheuristic algorithms used to detect the difference between before and after irradiation. Image enhancement is applied to images. PSO is the first algorithm; a fully automatic way to cluster an image using K-means principle. Finally, segment the image based on PSO, DPSO, and FODPSO. Image Segmentation using CS McCulloch Algorithm with OTSU is the second algorithm is used for generating stable random numbers for modeling *le´vy* flight in CS algorithm. The third algorithm is the Shuffled Frog Leaping Algorithm. The performance is evaluated by measuring PSNR and how it changes before and after the images.

2 Material and Methods

Types of radiation can be in the form of particles like alpha , beta , and neutron particles or electromagnetic waves like gamma rays and X-rays [7]. These types have different penetrating power and effecting on living material . Alpha particles are consisting of two positively charged protons and two neutrons that carry the most charge of all radiation types [8]. This increased charge leads to interact to a greater extent with surrounding atoms. The energy rapidly reduces by the interaction of the particle and reduces the penetrating power. It has a short range in air (1 -2 cm), for example, a sheet of paper can stop the alpha particles [9]. Beta particles are consisting of negatively charged electrons that carry less charge and are more penetrating than alpha particles [8]. For example , beta particles can go through a centimeter or two of living tissue, as beta particles are singly charged, lighter , and ejected at faster speed than alpha particles [10]. Gamma rays [11] and X-rays can go through anything less dense than a thick slab of steel, they are extremely penetrating . Gamma rays , like light , represent energy transmitted in a wave without the movement of material, just like heat and light, It is a form of electromagnetic radiation. X-rays [12] are like gamma rays, but with lower energy photons, it distinguished only in their source. Gamma rays emanate from the nucleus of a radioactive atom , while x-rays emanate from outside the nucleus of a radioactive atom. X-rays examples are radiowaves, infrared radiation, ultraviolet radiation and microwaves. Electromagnetic radiation can be described in terms of a stream of photons. Neutrons can be in two ways, artificially produced neutrons are emitted from an unstable nucleus as a result of atomic fission or nuclear fusion or naturally as a component of cosmic radiation. Neutrons have a very high penetrating power when interacting with material or tissue . Fig. 1 shows the penetrating power of different types of radiation [2].

The microbial contamination of food takes place at every stage of food processing. The primary production stage the microbial contamination takes place due to soil, irrigation water and worker. The worker and washing water are in the processing stage. The improper storage at the consumption stage can be caused in the microbial contamination. Many microbes such as viruses and bacteria are associated with fruits and vegetables. So the radiation processing of food has many benefits, as it delayed ripening of fruits and vegetables, inhibition of sprouting, and disinfestation of insect pests [13].

Three different meta-heuristic optimization algorithms are used to discuss the effect of radiation on the food images, how the food changes before and after taking radiation dose.

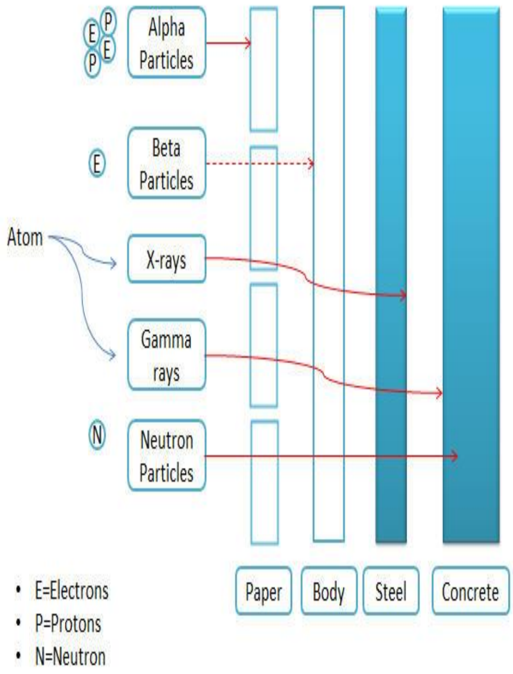


Figure 1: Penetrating Power of Different Types of Radiation

2.1 Algorithm 1: Particle Swarm Optimization

PSO was initially developed by Kennedy and Eberhart in 1995 [14]. The researchers adopted due to its optimization accuracy to solve variety of engineering optimization problems. In this decade PSO has gained attention from researchers, approaches are widely efficient in image segmentation application. PSO is one of the most well-known meta-heuristic optimization algorithm, based on swarm intelligence [15]. PSO is a population-based optimization model which improves the candidate solutions , known as particles , iteratively with respect to a measure of quality or fitness function [16]. It defines a particle k by its position x_k and its velocity v_k. The swarm moves across the search space at each time step *t* and every particle changes its position based on the velocity, defined as shown in eq. 1 [17]:

$$v_k(t+1) = w * v_k(t) + r_1 * c_1 * \left(p_{best_k} - x_k(t)\right) + r_2 * c_2 * (g_{best} - x_k(t)) \quad (1)$$

where w controls the oscillation of the particle , p_{best_k} is the personal best position of the particle k, g_{best} is the global best position in the swarm, c_1 and c_2 are the swarm history and swarm influence factors , respectively, and $r_1, r_2 \in (0, 1)$ are random uniform variables . $x_k(t)$ is updated as in eq. 2, and it represents the particle position at time t:

$$x_k(t+1) = v_k(t+1) + x_k(t) \quad (2)$$

The PSO is useful and ideal due to its minimal parameter usage , and it can be used in numerous applications with different needs [18]. The use of PSO algorithm has several benefits:

1. PSO is easy to use due to the absence of crossover and mutation procedure in GA, and the PSO algorithm is dependent upon the speed of particles. Thus, the data are transferred to the new particles solely through the optimal particles.
2. The PSO algorithm offers a historical record of the particle swarm movements due to its excellent memory.
3. Only a small number of parameters is required to use and adjusted in addition to the absence of complexity in the PSO algorithm structure compared with other metaheuristic algorithms .
4. The PSO algorithm possesses the capability to produce a precise outcome at the start of the search operation.

In search of a better model of natural selection using the PSO algorithm , the Darwinian Particle Swarm Optimization (DPSO) was formulated by Tillet [19], in which many swarms of test solutions may exist at any time . Each swarm individually performs just like an ordinary PSO algorithm in which natural selection (Darwinian principle of survival of the fittest) is used to enhance the ability to escape from local optima . When a search tends to a local optimum, the search in that area is simply discarded and another area is searched instead [20]. In this approach, at each step, swarms that get better are rewarded (extend particle life or spawn a new descendent) and swarms which stagnate are punished (reduce swarm life or delete particles). To analyze the general state of each swarm , the fitness of all particles is evaluated and the neighborhood and individual best positions of each of the particles are updated. If a new global solution is found, a new particle is spawned. A particle is deleted if the swarm fails to find a fitter state in a defined number of steps. Some simple rules are followed to delete a swarm , delete particles, and spawn a new swarm and a new particle: i) when the swarm population falls below a minimum bound , the swarm is deleted; and ii) the worst performing particle in the swarm is deleted when a maximum threshold number of steps without improving the fitness function is reached. Like the PSO , a few parameters also need to be adjusted to run the algorithm efficiently : i) initial swarm population; ii) maximum and minimum swarm population; iii) initial number of swarms; and iv) maximum and minimum number of swarms . The main advantage of DPSO is that it is capable of working with multiple swarms at a given time. The PSO is of remote use if the search space is found to be discrete . The proposed DPSO algorithm is being inspired by the binary PSO algorithm. The key concept of DPSO is to run multiple simultaneous PSO algorithms, each one depicts a swarm [21]. The FODPSO , proposed by Couceiro [22], is an extension of the DPSO in which fractional calculus used to control the convergence rate of the algorithm [23]. Fig. 2, 3 and 4 show the flowcharts for the different PSO algorithms, PSO algorithm, and DPSO algorithm respectively.

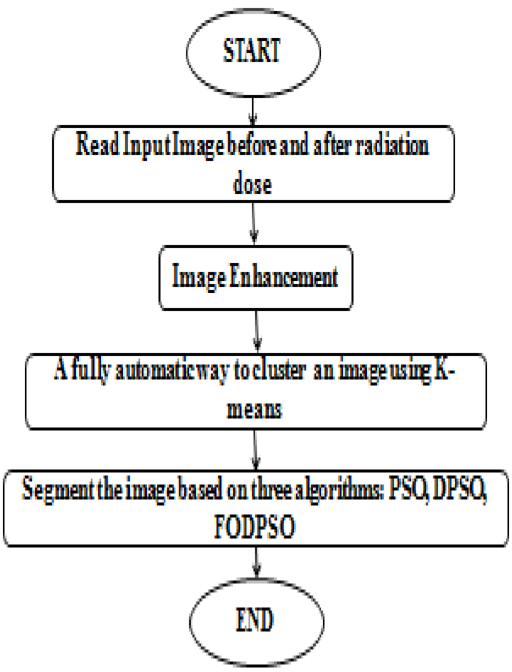


Figure 2: Flowchart for the Different PSO Algorithms

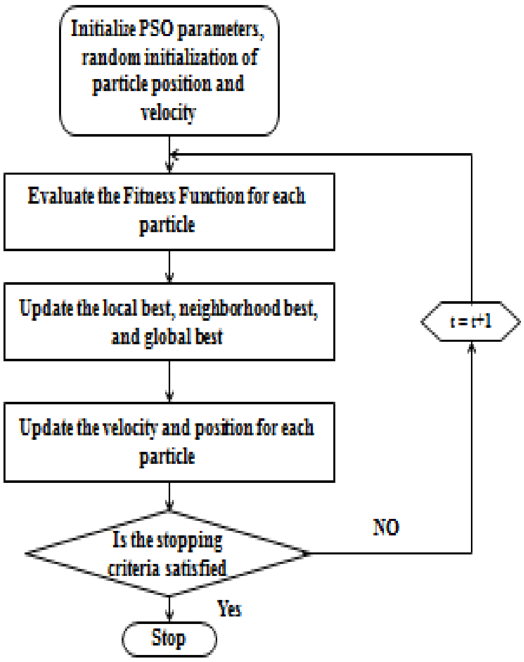


Figure 3: Flowchart for PSO Algorithm

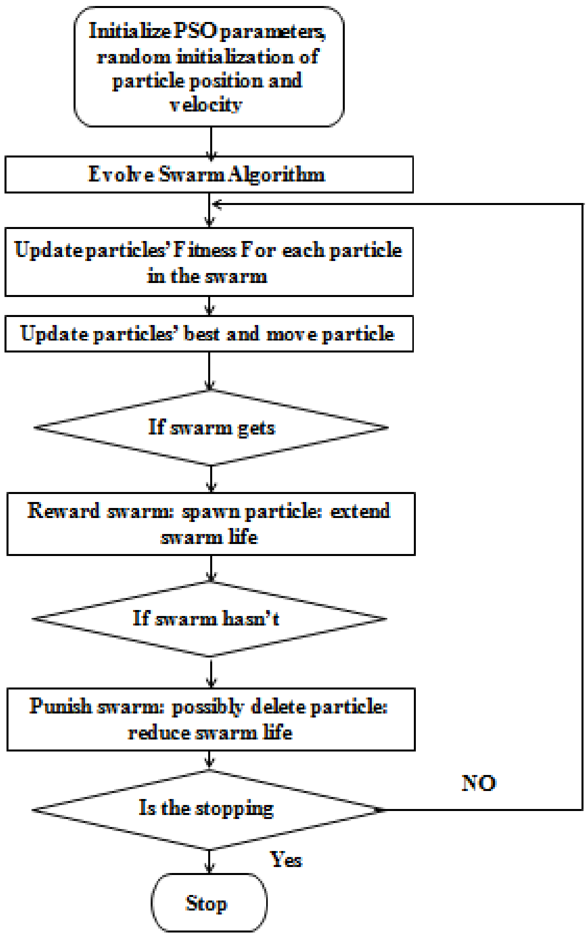


Figure 4: Flowchart for DPSO Algorithm [23]

2.2 Algorithm 2: Cuckoo Search

It is also a meta-heuristic optimization algorithm [24] evolved due to the captivating reproduction policy of certain Cuckoo species developed by [25]. They lay eggs other bird's nest and even remove host eggs to increase the probability of their eggs getting hatched. These birds exhibit mainly 3 types of blood parasitism : (1) Intra-specific (2) Cooperative breeding (3) Nest takeover . Some species of host birds simply throw out cuckoos eggs or even leave their nest and put up a new one when alien eggs are discovered . Certain Cuckoo species are clever enough to mimic the color and texture of the egg of the host birds which reduces the chances of being caught. For simplifying the whole process we consider these three conditions:

1. One egg will be laid at a time by each cuckoo in any nest chosen randomly .
2. Nest which have the best quality eggs are carried over to the forthcoming generation.
3. The probability of host species discovering cuckoo's egg lies within the probability range *pa* ∈ [0, 1] and the total number of nests is fixed.

The Cuckoo search algorithm starts its initial iteration with a randomly generated solution set obtained by eq. (3). Once the host species discovers the cuckoo's egg in its nest , it will abandon the nest or throw away that egg which is implemented in the algorithm by replacing p_a of the total number of nests by new . Each egg corresponds to a feasible solution and its fitness value is calculated. A new solution is formed using the concept of *Le´vy* flight which is given by eq. (4). *Lévy* flight modeling is random number generation using *le´vy* flight proceeds through two steps, which includes the proper choice of flight direction and generation of steps which obey *le´vy* distribution.

$$x_{i,j} = x_j^{min} + rand(0,1)(x_j^{max} - x_j^{min}) \qquad (3)$$

Where $i = 1, 2, \ldots, SN$ in which SN denotes the number of food sources , $j = 1, 2, \ldots, n$ where n denotes the number of optimization parameters and $x^{min}{}_j$ and $x^{max}{}_j$ are the minimum and maximum bounds for dimension j, correspondingly .

$$x_i(t+1) = x_i(t) + \alpha * le\acute{}vy(\lambda) \qquad (4)$$

Where α is the step size. *Le´vy* flight simulates random walks where in the step sizes follow *le´vy* distribution given as eq. (5):

$$le\acute{}vy(\lambda) = t^{-\lambda}; 1 < \lambda \le 3 \qquad (5)$$

The nonlinear relationship of variance of *le´vy* flight as given in eq. (6) helps in exploring large unknown search spaces more efficiently compared with those models with linear relationship.

$$\sigma^2(t) \sim t^{2-\beta}; 1 \le \beta \le 2 \qquad (6)$$

The iterative process continues till it reaches the global optima. This preferably avoids the problem of being caught in local optima which usually appears in PSO algorithm. The flowchart for the CS used to detect the effect done on the fruits and vegetable before and after radiation dose and the flowchart for CS algorithm are given in fig. 5 and 6 respectively.

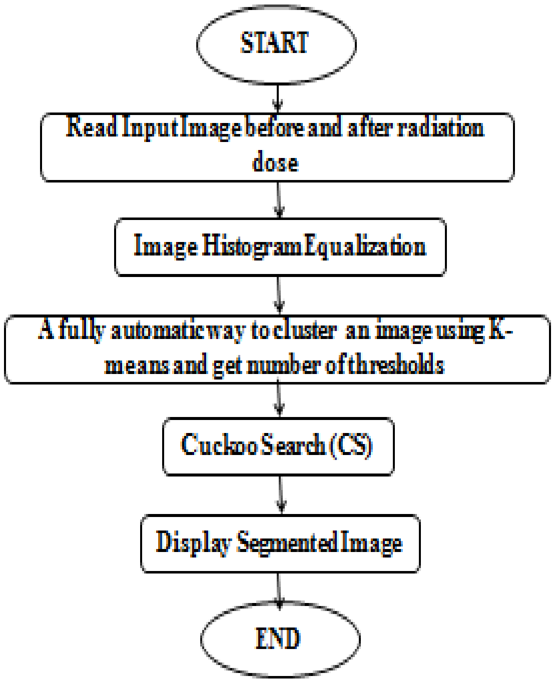


Figure 5: Flowchart for the CS algorithm used to detect the effect of radiation dose

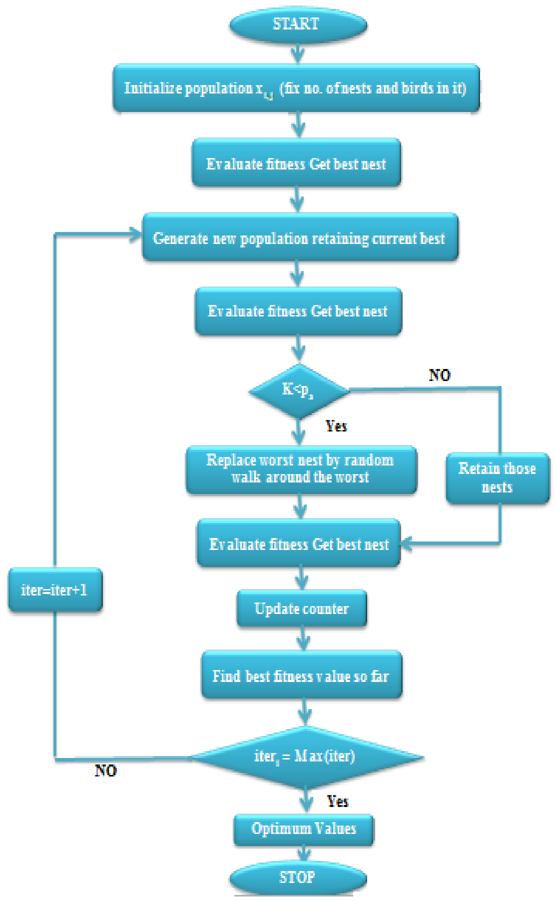


Figure 6: Flowchart for Cuckoo Search Algorithm

2.2 Algorithm 3: Shuffled Frog Leaping Algorithm

Optimization is one of the difficult problems [26]. Algorithms that solve these kinds of problems are varied. Among them, we cite the meta-heuristic family that contains stochastic optimization algorithms . SFLA is a new metaheuristic that mimics the principle of a group of frogs evolution that searches discrete locations containing as much food as available [27]. GA is an evolutionary algorithm which is inspired by natural selection and survival for the fittest in the natural world, and PSO , which is based on swarm intelligence, is inspired by the foraging behavior of animals. By combining the benefits of the last two algorithms, researchers have proposed the Shuffled Frog Leaping Algorithm (SFLA) imitating the behavior of shuffled frogs seeking the location that contains the maximum amount of food available [27-31]. SFLA combines the advantages of PSO which inspires its principle from the herding behavior of animals [32] like fish floquant and from GA which is a research technique developed by Holland [33] with such characteristics as great capability in global search and easy implementation . The latter models the principle of natural evolution. SFLA has demonstrated effectiveness in various optimization problems that are difficult to solve using other methods, such as water distribution and ground water model calibration problems [30].

Generally , when applying SFLA to an optimization problem , each frog has a different solution from others according to its adaptability evaluated by its fitness function [34]. The entire population of frogs is divided into a predefined number of subsets called memplexes . Frogs of each memplex have their own strategy to explore the environment in different directions. After a predefined number of memetic evolution , the exchange of information between memplexes takes place in a procedure of shuffling. This procedure must ensure that the evolution toward a particular interval is free from all prejudices. Memetic evolution and shuffling are performed alternatively until reaching the convergence criterion or otherwise until a stopping criterion . Steps of SFLA are given below.

Step 1:Initial population

Initial population Xi, $(i = 1, 2, . . . , F)$ of F frogs , in which individual frogs are equivalent to the GA chromosomes , is created randomly .

Step 2: Sorting and distribution

All frogs are sorted in descending order based on their fitness values and divided into m memplexes , each memplex containing p frogs (i.e., $F = m \cdot p$); the frog that is placed first moves to the first memplex, the second one moves to the second memplex , the p^{th} one to the p^{th} memplex, and the $(p + 1)^{th}$ returns to the first memplex , etc.

Step 3: Memplex evolution

Within each memplex, the frogs having the best and the worst fitness are identified, respectively , by Xb and Xw. The frog with the best fitness in the whole population is identified by the global best Xg. During the evolution of memplexes, worst frogs jump to reach the best ones using eq. (7) and (8), which are similar to the PSO equations .

$$S = rand(X_b - X_w) \tag{7}$$

$$IX_w = X_w + S;\ \ S < S_{max} \tag{8}$$

Where S indicates the jump step of the worst frog , IX_w is the improved worst solution, rand is an arbitrary number in the range [0, 1], and S_{max} is the maximum jump distance. Eq. (7) and (8) are repeated for a predefined number of iterations in order to obtain a better result than X_w. If these equations do not improve the worst solution , X_b is replaced by X_g and adapted to eq. (9).

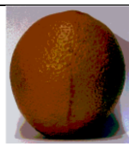
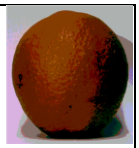
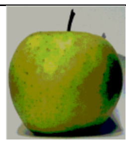
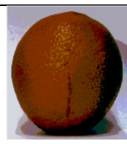
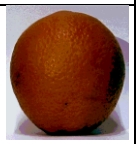
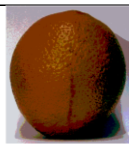
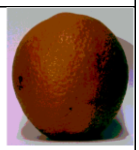
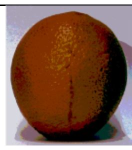
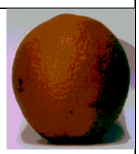
$$S = rand(X_g - X_w) \quad (9)$$

If eq. (8) and (9) do not improve the worst solution , a new position is generated arbitrarily .
Step 4: Shuffling
After a defined number of memplex evolution stages, all frogs of memplexes are collected and sorted in descending order again based on their fitness . Step 2 divides frogs into different memplexes again , and then step 3 is achieved.
Step 5: Terminal condition
If a predefined solution or a fixed iteration number is reached, the algorithm stops.

3 Results and Discussion

The radiation unit used in this paper is in Egyptian Atomic Energy Authority (EAEA). The images took by cannon digital camera 12.1MP. The experiments are done on Green Apple, Cucumber, and Orange that exposed to radiation dose 1 KGray. This paper introduced three different algorithms in order to detect the effect of irradiation process. Table 1 shows the effect of radiation dose on fruits and vegetable images using three different algorithms. Table 2 shows the PSNR and Time for the images before and after the irradiation. PSNR shows the difference between before and after radiation dose. SFLA takes time than the others and PSNR is lower than the other algorithms. Fig. 7-14 show the histogram for each image before and after irradiation.

Table 1: The effect of radiation dose using the three different algorithms

		Green Apple	Cucumber	Orange Front	Orange Back
PSO	Before				
	After 1KG				
DPSO	Before				
	After 1KG				
FODPSO	Before				
	After 1KG				

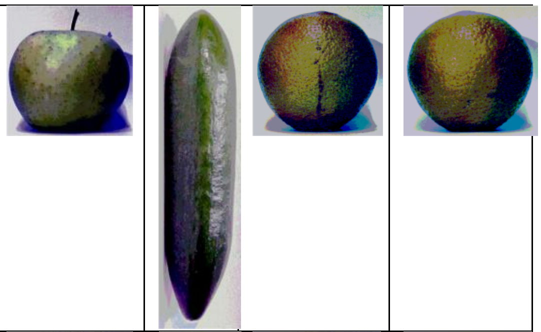
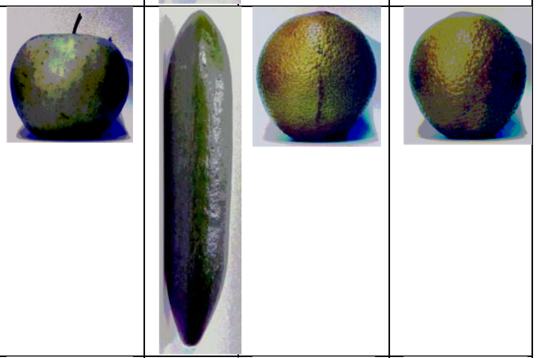
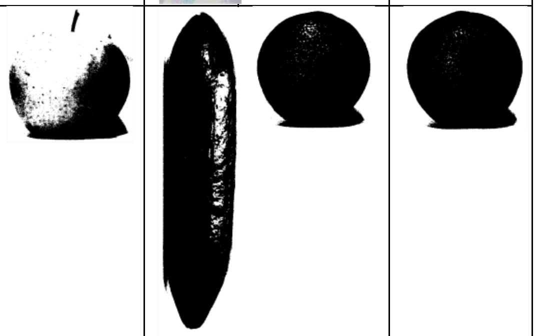
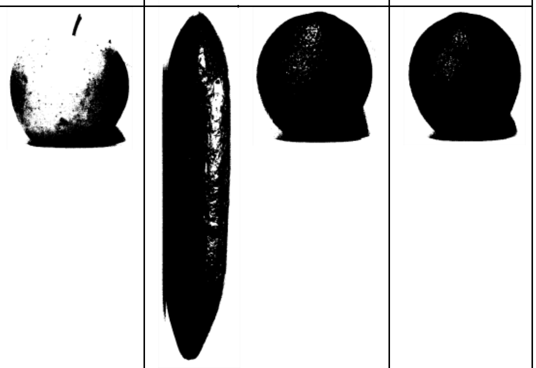
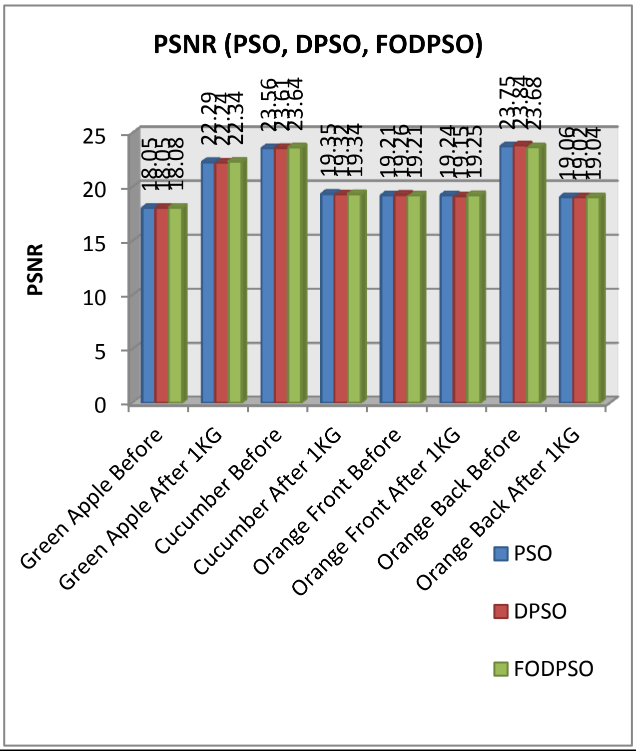
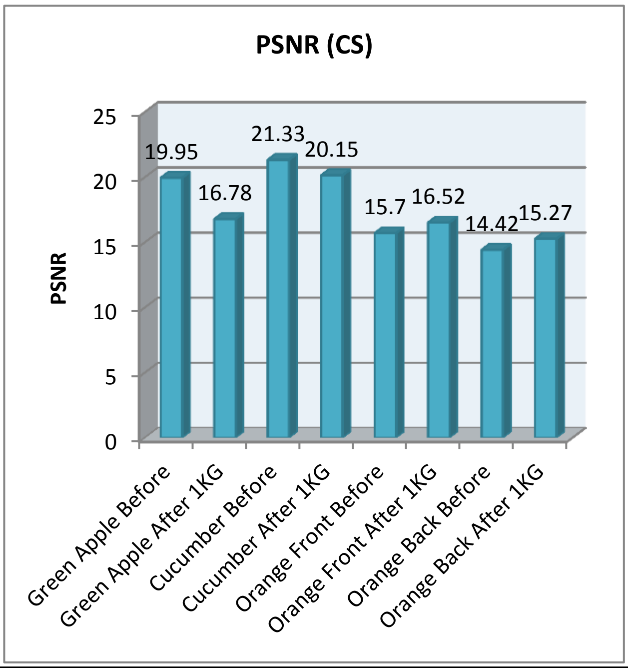
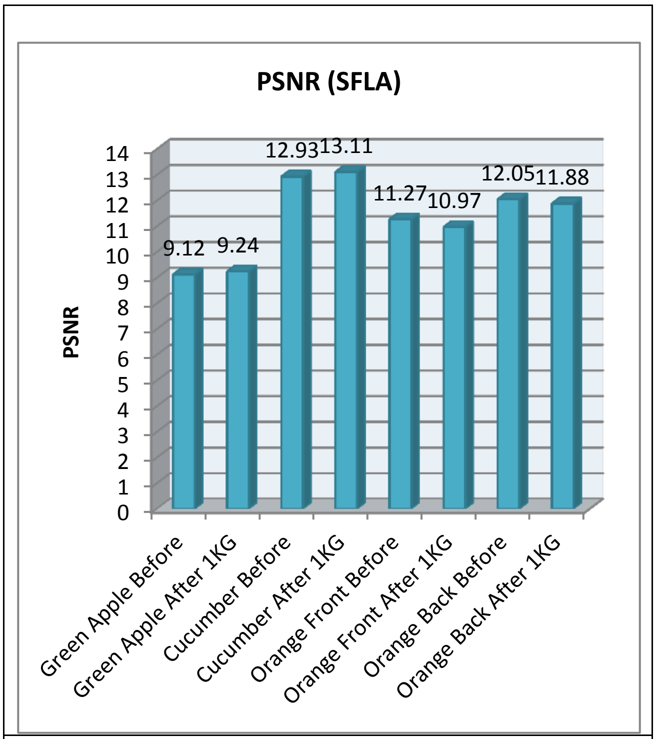
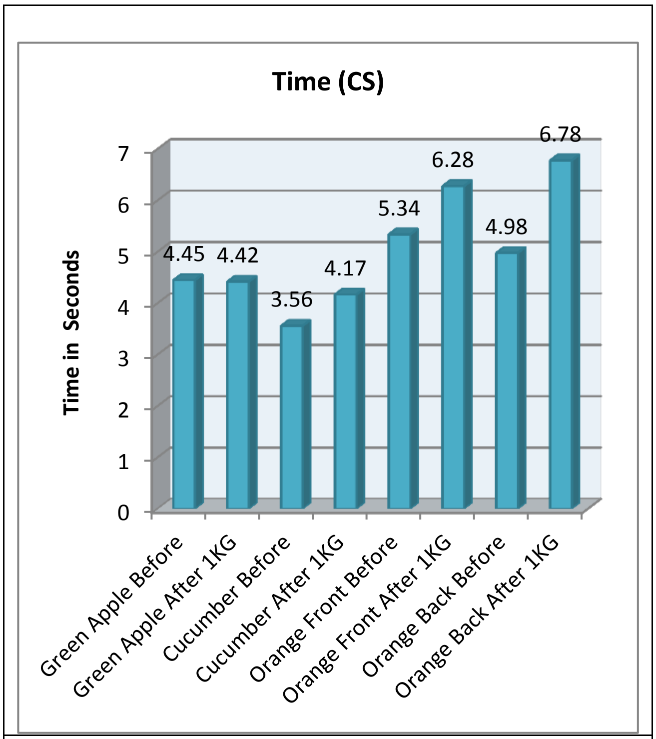
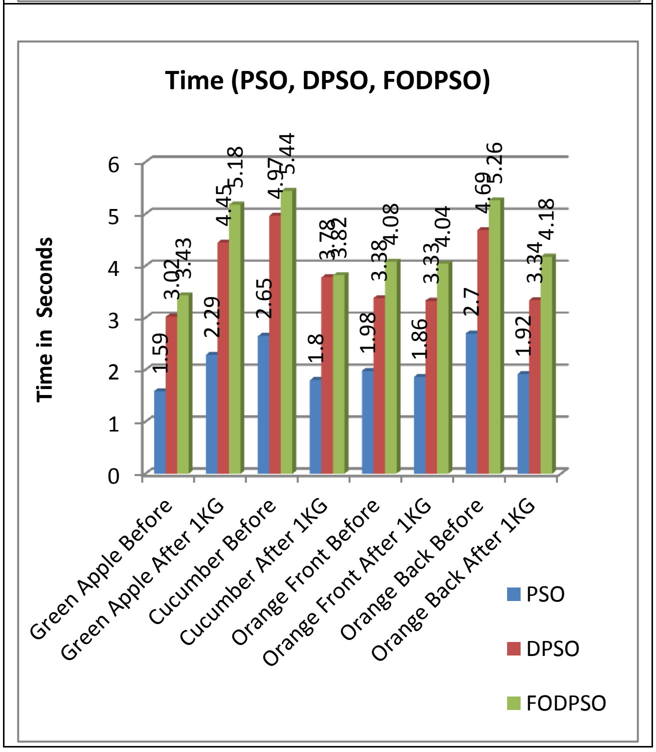
Cuckoo Search	Before	
	After 1KG	
Shuffled Frog Leaping Algorithm	Before	
	After 1KG	

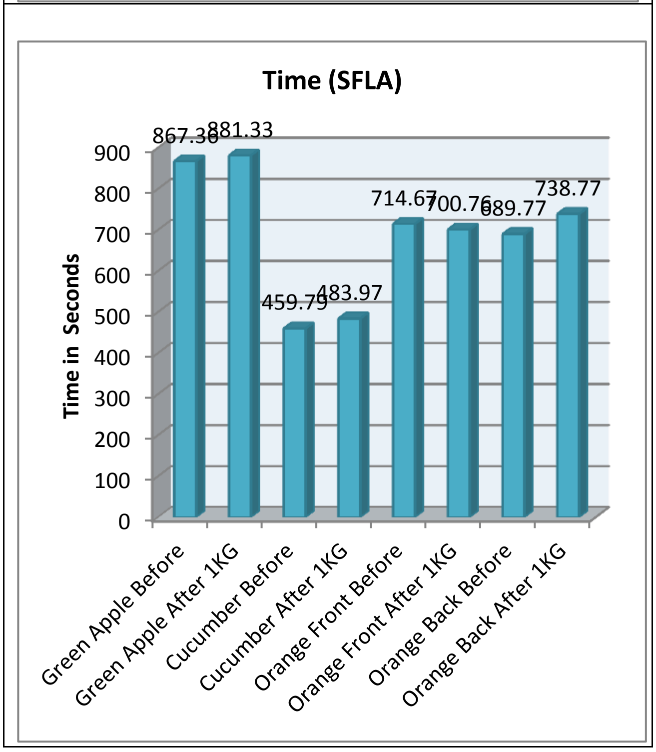
Table 2: Performance Comparison for the PSNR and Time before and after the irradiation

Results




PSNR (SFLA)
PSNR
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
9.12
9.24
12.93
13.11
11.27
10.97
12.05
11.88
Green Apple Before
Green Apple After 1KG
Cucumber Before
Cucumber After 1KG
Orange Front Before
Orange Front After 1KG
Orange Back Before
Orange Back After 1KG


Time (CS)
Time in Seconds
0 1 2 3 4 5 6 7
4.45
4.42
3.56
4.17
5.34
6.28
4.98
6.78
Green Apple Before
Green Apple After 1KG
Cucumber Before
Cucumber After 1KG
Orange Front Before
Orange Front After 1KG
Orange Back Before
Orange Back After 1KG


Time (PSO, DPSO, FODPSO)
Time in Seconds
0 1 2 3 4 5 6
1.59 3.02 3.43
2.29 4.45 5.18
2.65 4.97 5.44
1.8 3.78 3.82
1.98 3.38 4.08
1.86 3.33 4.04
2.7 4.69 5.26
1.92 3.34 4.18
Green Apple Before
Green Apple After 1KG
Cucumber Before
Cucumber After 1KG
Orange Front Before
Orange Front After 1KG
Orange Back Before
Orange Back After 1KG
PSO
DPSO
FODPSO


Time (SFLA)
Time in Seconds
0 100 200 300 400 500 600 700 800 900
867.38
881.33
459.79
483.97
714.67
700.76
689.77
738.77
Green Apple Before
Green Apple After 1KG
Cucumber Before
Cucumber After 1KG
Orange Front Before
Orange Front After 1KG
Orange Back Before
Orange Back After 1KG

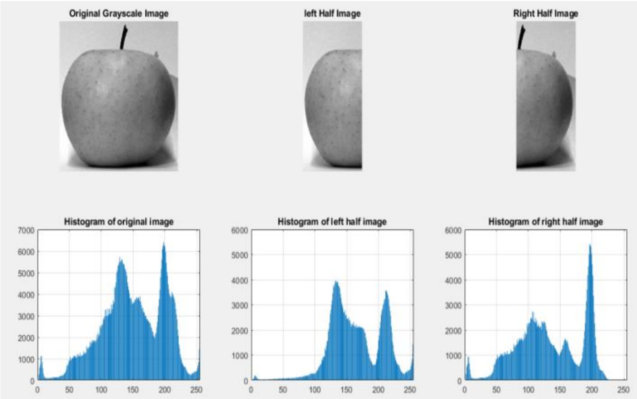


Figure 7: Histogram for the green apple before radiation dose

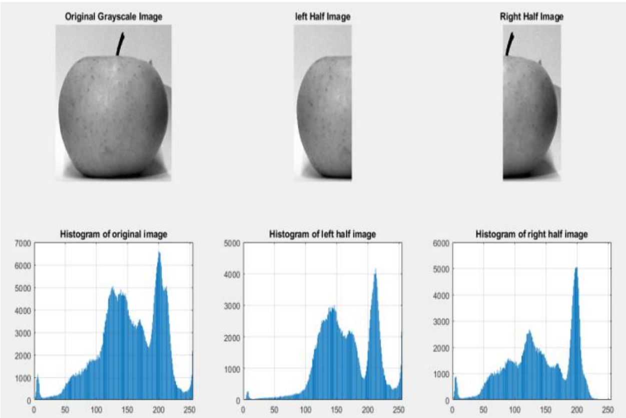


Figure 8: Histogram for the green apple after radiation dose (1KG)

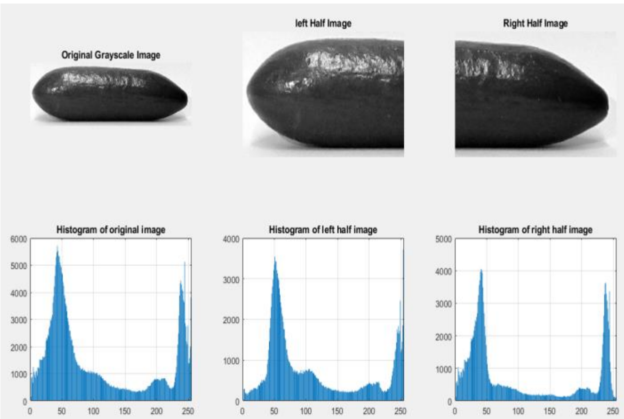


Figure 9: Histogram for the Cucumber before radiation dose

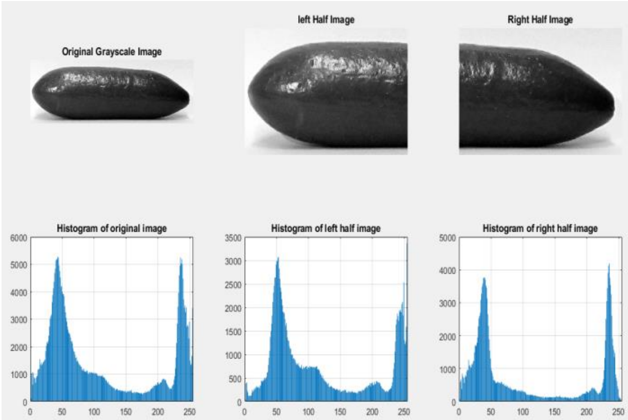


Figure 10: Histogram for the Cucumber after radiation dose (1KG)

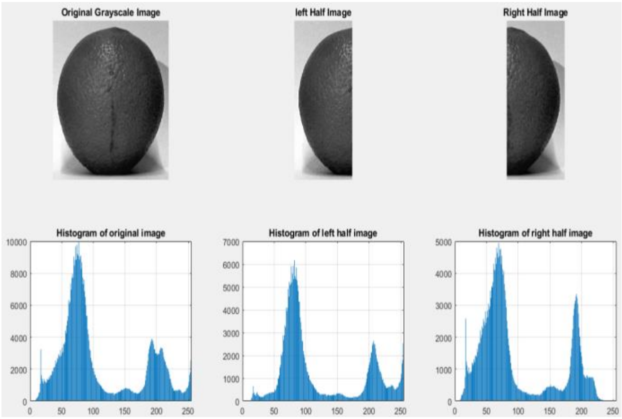


Figure 11: Histogram for the Orange Front before radiation dose

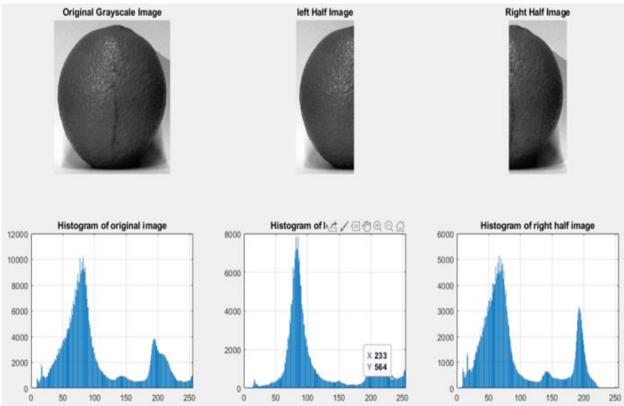


Figure 12: Histogram for the Orange Front after radiation dose (1KG)

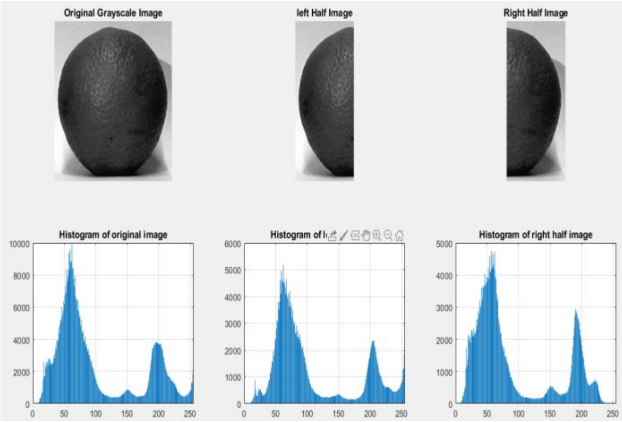


Figure 13: Histogram for the Orange Back before radiation dose

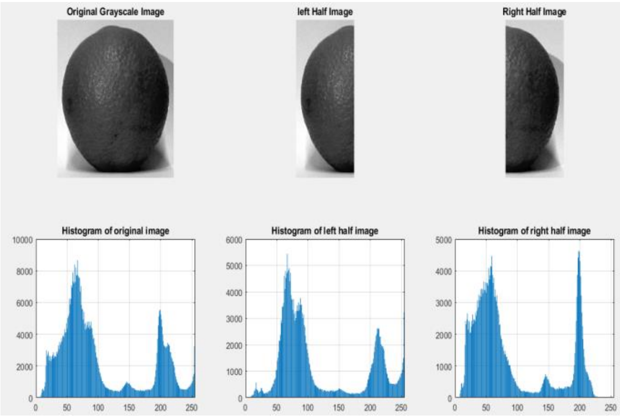


Figure 14: Histogram for the Orange Back after radiation dose (1KG)

4 Conclusion

Food irradiation is a processing technique that exposed food to a source of ionizing radiation, such as electron beams, X-rays , or gamma radiation to preserve food and inactivate food spoilage organisms , including bacteria, and yeasts . It’s effective in the extension of shelf-life of fresh fruits and vegetables by controlling the normal biological changes that can delay fruit ripening , or prevent vegetables from sprouting . In this paper, discuss the effect of the irradiation on fruits and vegetable by image segmentation using three different metaheuristic algorithms. The three algorithms are: (1) PSO, DPSO, and FO-DPSO, (2) CS, and (3) SFLA. The experiments are done on Green Apple, Cucumber, and Orange that exposed to radiation dose 1 KGray. The algorithms succeeded in discovering the effect of radiation even if it isn’t visually recognized by measuring the PSNR and the histogram of the images before and after.

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Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

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