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Neurobiology of Sweet Cravings: The Brain's Reward System Response to Hedonic Eating

Nour Shakir Rezaieg

Anbar Directorate of Education, Iraq.

E-mail: nourshakir123@gmail.com

ABSTRACT

Background: *Energy homeostasis is not an easy algebraic sum of energy intake and energy spending, where it is a dynamic process affected by affects by the relation between energy expenditure and food intake. By complex nervous system including the hypothalamic centers and peripheral satiety system the energy homeostasis is controlled. Peripheral satiety mechanisms released peptides and hormones which in turn regulate metabolism or impacts on satiation. Sweet foods have high calories disrupts appetite regulation and induce the pleasure and reward system, so, it count to be an main source of stimulation that may leads to overeat and contribute to the evolution of the obesity. Sweet foods consume impact on hunger-satiety mechanism, assisting starting of consumption in absence of energy needs and keeping of feeding in spite of intake of huge food loads that risk homeostasis. consumption of too much amounts of sweet foods depend on mechanisms that advance behaviors addictive-like, and on bypassing the neuroendocrine cues that protect inner environment..*

Keywords: Sweet addiction, Dopamine, Hypothalamus, Sugar.

Article Information

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INTRODUCTION

In human the appetite is accurately regulated through an intricate system of hormones, neural cues and outer stimuli, that regulate food ingestion . This system can be divided into the central regulation including arcuate nucleus (ARC) of hypothalamus, and the peripheral regulation by hormones that are secreted in the intestine or in another places, such as: thyroid gland, adrenal gland and reproductive glans (1) In order for the system to function optimally, it requires a delicate balance of cues. On the other hand, irregularity of these signals leads to imbalance in the energy input than to the energy output, thus lead to weight gaining and obesity (2) (Fig1).

In the gut cells the gut hormones are differentially secreted response to nutrient variation, thus generating a fasting and fed secretory profile, To the side of the peptides that produced by adipose tissues the gut hormones are crucial for the homeostatic control of the body mass via modulating foods consumption and energy spending . Gut hormones mediate their effects directly by acting on areas of the brain. (3).

The human intestines are highly metabolically active and act as a major endocrine organ, playing an important role in energy homeostasis. Human gut produce nearly one hundred active peptides and express more

than thirty genes responsible for encoding the gut hormones (4).

The regulation of energy ingestion needed in order to typical bodily working and to maintain the body weight it is achieved by maintaining a homeostatic appetite. Yet, from an evolutionary terms, the homeostatic regulation of energy assimilation has developed over a period of time when food was frequently in tiny source, therefore having exact powerful orexigenic signaling (appetite-increasing or eat-stimulating), therefore, it might not be typical for the present obesogenic environment, where there is availability and accessibility of highly palatable foods in easily ways (5).

On the other hand, hedonic hunger refers to the hedonic eating, In other words, to intake of food high in fat and sugar just for happiness and not to keep energy homeostasis. In this state, the persons consume the food when is not in a condition of short-term energy depletion, and food is consumed uniquely as its rewarding properties (6). This kind of ingestion includes the dopaminergic paths in midbrain connected with addiction behaviors, and has the ability to overrule the homeostatic satiety cues, so, causing individuals to eat food even when they are full (7). This review aims to explain the sugar's influence on the brain, body weight and behavior to illuminate why and how sugar intake has been connected in the addictive behaviors.

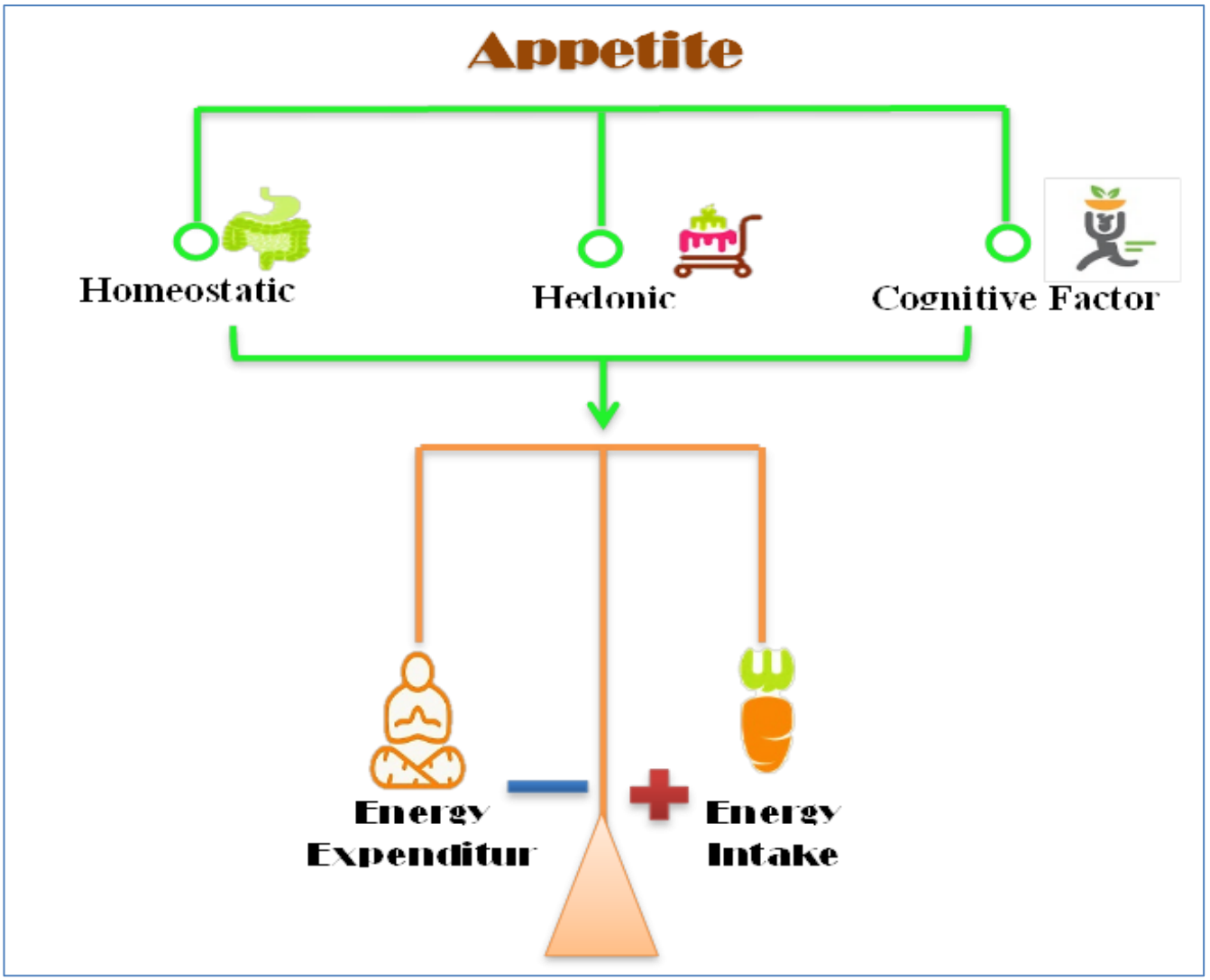

Figure (1): Shows the schematic representation of energy homoeostasis and impact factors. Each of hedonic, homeostatic and cognitive factors (green row) was grouped under the idea of appetite control (designed by researcher using Microsoft Word 10).

Neurobiological Basis of Energy Homeostasis

Energy expenditure is a continuous process, whereas the energy get by food consume is by nature discontinuous. For keeping the fat mass stable in the body, a mechanism ensure a balance between energy expenditure and energy intake is therefore needed, while the modern routs of life in developed countries tend to disarrange such the energetic balance (8).

One crucial structure in the domination of the energy balance is the hypothalamus (HT), a complex and small deep brain structure lied just above the brainstem and below of the thalamus (9).

Hypothalamus is composed of many nuclei. These nuclei include: the ventromedial nucleus (VMH), the lateral hypothalamic area (LHA), the paraventricular nucleus (PVN), and the arcuate nucleus (ARC). In ARC there are two groups of nerve cells: First group are orexigenic neurons [that express both neuropeptide Y (NPY) and agouti-related peptide (AgRP)], while second group: are anorexigenic neurons [that express proopiomelanocortin (POMC)]. Hunger activates appetite-stimulating neurons, whereas satiety activates appetite-suppressing neurons (10, 11).

Every these nuclei are connected, and obtain signals (information) from different regions. The signals may be of the central origin which originating in central nervous system (CNS) (like the vagus nerve), or may be of the peripheral origin which originating in the peripheral tissues and organs; such as: hormone signals (like leptin, insulin, cholecystokinin, and glucocorticoids), in addition to signals from the digestive tract (like ghrelin and peptide YY) (12). As for the length of time for the effect of these peptides, it is either: short acting peptides (its activity restricted to through and just after a meal) as cholecystokinin, or long acting peptides as leptin (13).

Energy intake and expenditure are two processes which are modulated by the two system orexigenic and anorexigenic system (14).

The orexigenic system is responsible for increasing the body weight over the encouragement of the hunger mechanisms and appetite mechanisms, and stimulation of inhibit energy expenditure mechanisms [15]. While, the anorexigenic system responsible for decreasing of the body weight through the exciting of the mechanisms that increase energy spending and decrease food eating (16).

Sweet Taste Perception and Weight Gain

Sugar is common term utilized to describe a category of molecules called carbohydrates, and its present in a broad diversity of food and drink. Glucose, fructose, sucrose, maltose, lactose, dextrose, and starch are all shape of sugar (17).

Sweet taste have the ability to direct food consumption and affect health, leading to overweight and obesity has been largely as a results overconsumption of sugars (18).

It is estimated that the popularity of obesity has tripled during the earlier five decades. According to the instructions of the World Health Organization (WHO), everyday energy consume from added sugars must not override 5–10% (19). Taste impacts eating ways and the want to consume specific products, which is connected with entire of energy presuming to the body through daily diet (20).

In humans, the taste is classify into five type: sweet, salty, bitter, sour and umami (a taste of amino acid or glutamate), also, there are a burly evidence refer to that the amino acid as a sixth taste form . Carbohydrates is the main source of sweet taste and sweet taste has been connected with food reward (21).

A sweet taste is one of five tastes recognized via the human taste buds, which be composed of sweet-taste receptors. In our body, there are diversity of sweet taste molecules which includes amino acids, proteins, carbohydrate, glycosides, polypeptides and glycerol. its receptors are spread through various organs such as: gut, brain, the tongue, lung, pancreas and lung (20).

The sweet taste receptors, in the brain, is plentifully expressed in the hypothalamic arcute nucleus (ARC) and the expression level of these receptor in the hypothalamus is impacted via metabolic conditions (22).

Sweet-taste receptors belong to G protein-coupled taste receptors. G proteins composed of three subunits are: Alpha (α) , Beta (β), and Gamma (γ) (, from largest to the smallest) (23). G proteins are so called because the one of the subunits is alpha (α)-subunit connects to the guanine nucleotides molecule. In inactive state, a guanine diphosphate (GDP) is binding to the α-subunit of each G protein. Next a ligand links to receptor on the external of a cell, the receptor changes form and active (24).

The binding of sweet taste molecules to the receptors, specifically the alpha subunit, leads to stimulate of the G protein, the activation of G protein lead to cascade of responses causes promoting of the suitable receptors lied on afferent nerve fibers which mediate the taste cue to brain centers, which includes the hypothalamus and from here the signal triggers the reward system (25).

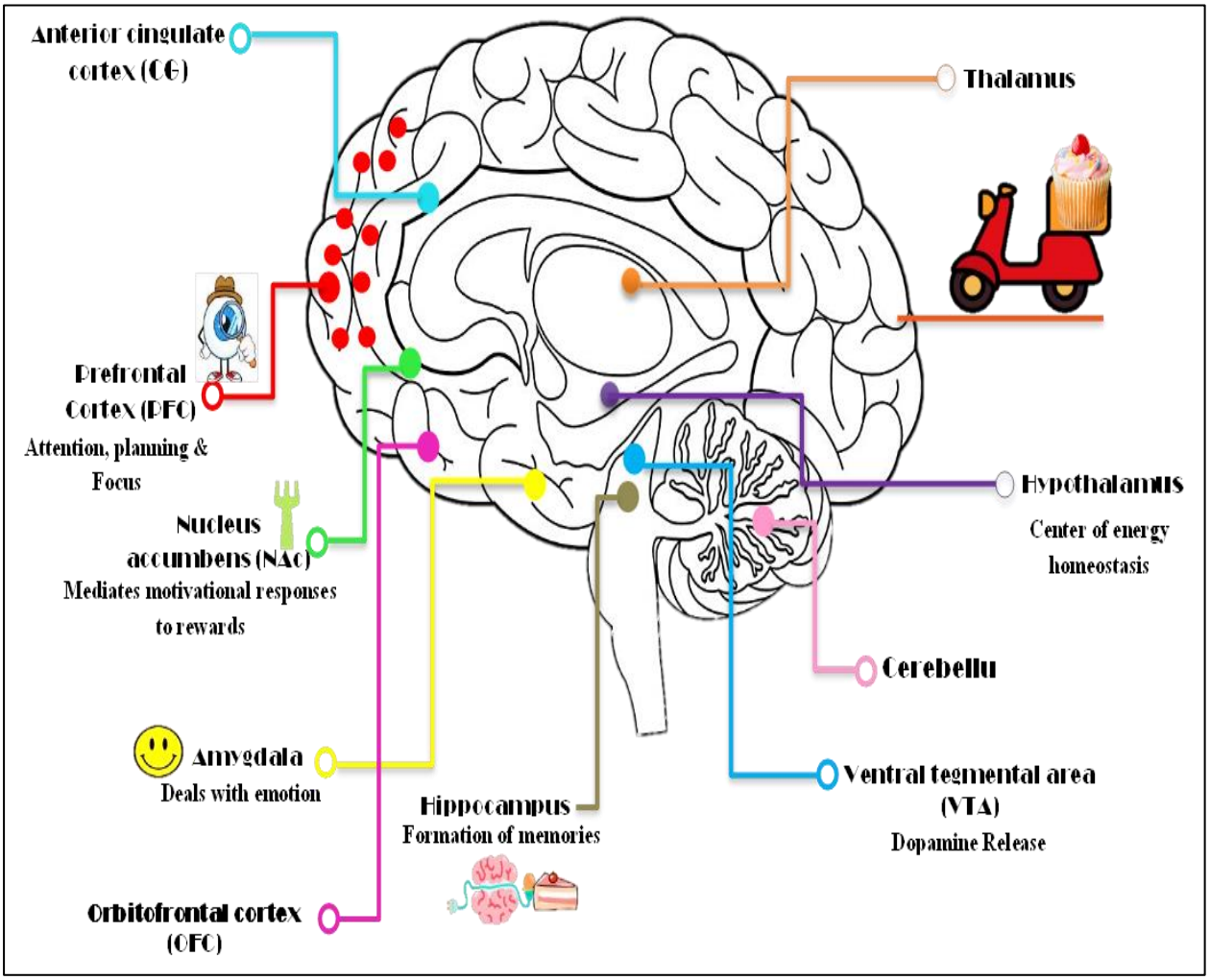

Figure 2: Shows reward pathway including the neural regions of the reward pathway are: Prefrontal Cortex (PFC), Amygdala (AMG), Ventral tegmental area (VTA) and Nucleus accumbens (NAc) (designed by researcher using Microsoft Word 10).

Reward System

The mechanisms regulating eating behavior are divided into two categories **:**

- **Homeostatic**
- **Rewarding (Hedonic)**

Homeostatic mechanisms are an increased willingness to eat after energy expending, then following eating, the person stop consuming more calories **.** The metabolic state of the body, activity levels, and the distribution of nutrients (carbohydrates, fats, proteins and minerals) all influence homeostasis (26).

Rewarding mechanisms is the motivation to ingest high palatable foods even after reaching the satiation point "set-point**"**. So, the interaction between these two systems sculpts us feeding behavior (27).

The mechanisms of central nervous system (CNS) that in charge of control food consumption have developed to sense the nutrient and the energy levels in the human and thus to organize suitable replies to control energy ingest and spending. This homeostatic system is very important for keeping of steady the body weight during long times of irregular energy availability (28) **.** The foods with high in sugar and fat, are powerful rewards that encourage consumption even when there is no need for energy and thus trigger activating reward system (29). Food eating and energy spending are regulated through the complex nervous system that includes both of hypothalamic centers and the peripheral satiety system that involve intestinal and pancreatic hormone (30). The hypothalamus is the main area of the brain that regulates food intake as it connects to calorie and nutritional needs (31) **.** In special, the arcuate nucleus (ARC) by its associations with another hypothalamic nuclei and extra-hypothalamic brain areas, involving the nucleus tractus solitarius (NTS), is controls food consume , in addition to its implicated in obesity (32). In addition to the neuropeptides involved in regulation of eating, each of dopamine (DA), cannabinoids, opioids and serotonin, they are also neurotransmitters but are involved in the rewarding effects of food (33).

Dopamine is a monoamine neurotransmitter made by the hypothalamus in the brain, has important role as a chemical messenger, communicating signals between nerve cells and the remainder of the body (34)**.** Dopamine is known a feel good hormone (happy hormone). It gives individuals a sense of desire, is part of the reward system. From an evolutionary standpoint, this system is designed in order to reward the individuals when they are doing the things to survive such as: drink, eat, and breed (35).

As humans, our brains are hardwired to seek out behaviors that secrete dopamine in order to activate our reward system. So, when individuals are doing a pleasurable thing, the brain products a large quantity of dopamine leads to sense good and thus the individuals seek more of that feeling. For this reason why sweets are so addictive, that gives us the feeling that we are on top of the world and we lack to do again that experience (36). Dopamine acts mainly through its projections from the ventral tegmental area (VTA) and substantia nigra (SN) to the nucleus accumbens (NAc) (37) . Other dopamine sites are also implicated, which includes:

- ✓ **Dorsal striatum (caudate and putamen)**
- ✓ **Cortical (orbitofrontal cortex) (OFC), anterior cingulate cortex (CG) and insula)**
- ✓ **Limbic regions (hippocampus and amygdala) and cingulate gyrus (CG).**
- ✓ **The lateral hypothalamus** (3) (Fig 2).

Glucose: Brain's Compulsory Fuel

Our body acts on sugar, especially glucose. Term glucose derived from Greek word "glukos" which means sweet (sweet taste). Glucose is the main source of energy for every cells that make up our body including neurons (39).

Because of our brain is so wealthy in neurons (nerve cells), therefore, it is the organ that consumes the most energy in the body, consuming approximately 20% of glucose-derived energy. In humans, the brain forms for approximately 2% of the body weight, making it the major consumer of glucose (40).

The human brain is composed of a dense network of nerve cells, which are be always active in order to carry out many important functions even during sleep, so the brain need to energy which come from glucose to sustain this activity (41).

In order to maximize our existence as a species, we own the brain system (innate brain system) that makes us prefer sweet flavors because of they are a large source of energy to support our bodies, clearly, that the our brains require a large amount of sugar; where without it, we fast lose the capacity to think and slide into a coma (42).When the levels of blood glucose go very low, as they do throughout hunger, the brain competes with other organs of body to get glucose. The brain can keep up its great level of activity in these conditions by severely managing its portion of glucose [43].

The brain achieves this via two primary mechanisms:

First: when its cells run out of energy, it draws glucose straight from the blood.

Second: it restricts the quantity of glucose available to the rest of the body so that the brain has more of it (44).

For survival, these mechanisms are very important. The brain cannot use fatty acids directly as fuel, unlike the liver and muscles (including the heart). So, your brain wants you to eat a lot of sugar and other simple carbohydrate sources, like a donut, when you wake up in the morning after a long period of fasting. In sometimes, what your brain wants is not evermore good for the body (45).

For instance, in early morning after you take a healthy breakfast, but yet, you are still feeling hungry, Why? Your brain is not cooperating with you because it is not pleased with that breakfast since it lacked one important factor that the brain urgently needs is sugar. And that's because you have been fasting since dinner last night and leads to decrease levels of sugar in the blood(46).

Your brain views sugar as essential and will use any means at its disposal to get you to consume it as frequently as possible, in order to operate normally. So, your brain needs sugar, typically in the form of glucose (47).

The brain has billions of neurons, each of which needs sugar to continue producing energy and interacting with other neurons, since, the neurons can only stand a total deprivation of sugar for a little minutes before they begin to die (48).Once inside the brain, sugar is as well utilized to make a so principal neurotransmitter chemical named acetylcholine. Acetylcholine (ACh) is a neurotransmitter that transmits cues between neurons in the central nervous system (CNS) and the peripheral nervous system (PNS) (46).

Acetylcholine plays an key role in numerous different body functions such as, stimulates muscles to contract (It can be found in all motor neurons), allow to learn and memory (It is also found in many brain neurons), as well involved in attention, arousal, neuroplasticity, and regulating sleep (49). Acetyl groups produced by the metabolism of sugar and choline, which are received from food sources, are used by the brain to form acetylcholine. Also, choline can be obtained through our diet that rich in lecithin sources (50).

Lecithin is not a one only material, but it is a category of chemicals that belongs to compounds called phospholipids. Phospholipids are a kind of fat that assists keep the integrity of cells, and they are very important to the functioning of the brain, heart, nerves, eye, liver, and another organs (51).

Lecithin could be get in numerous various baked goods groups such as: breads (buns, rolls, bagels, biscuits and loaf breads), bars, cookies, sweets (cakes, pies and cheesecakes), pizza, sweet foods (sweet rolls, donuts and coffee cake) and tortillas. So, the delicious donut covered with chocolate is the first substance your brain asks for in the morning, which will supply it with all energy it needs to be attention and learn new thing (51, 52).

The Our Brain Wants Sugar, then More Sugar!

Sugar is common word utilized to describe a group of molecules called carbohydrates , and it is present in diversity of food and drink. Connecting the sweetness sensing together a pleasurable experience is instinctive, as sugar taste paths have developed to cue the existence of potentially nutrients in an environment of restricted food availability, so make us attend to like sweet (sugary) taste (53). In the present time, sweeten are added to many dietary product as conservative agents and sweetening , texture exhauster or taste, therefore, largely intake as part of the diet (54).

Glucose is a natural sugar and commonly consumed. The main source of energy for brain is glucose and its metabolism is keep under tight ruling. 20% of glucose derived from energy in the human body was consume by the brain (55).

Glucose intake has impacts on the neuronal activity and functional connectivity through the brain in zones that shared in the reward and nutrition behavior. As well, the levels of blood glucose effect brain responses and activity and central nervous system (CNS) regulation of the glucose balance (homeostasis), therefore, that the consumption of glucose could possess burly and extensive impacts on the brain, nutrition behavior and satiety marking (53).

In hypothalamus, especially in arcuate nucleus (ARC) there are two types of glucose-sensing nerve cells. First type: is the glucose-responsive nerve cells, these type of cell are stimulated via elevated glucose concentrations, while inhibited via small glucose concentrations (they are thought to be satiety nerve cells). Second type: are glucose-sensitive nerve cells, which are stimulated via small glucose concentrations and inhibited via great glucose concentrations. (this type are thought to be orexigenic nerve cells) (56).

The fact that eating sweet-tasting foods is a powerful stimulant that activates the reward system, and so on, the pleasure and satisfaction get from their intake vary depend on the sweeteners present (57).

The reward path is linked to zones of the brain that be in control of behavior and memory. It starts in the ventral tegmental area (VTA), where nerve cells secrete dopamine to make the person sense pleasure, from here the brain starts to make links between the pleasure and the activity, thus, ensuring that will repeat the behavior. Sometime the reward pathway is useful but other times, it can be destructive (58).

In last years, the notion of food addiction has received a lot of attention. It has been suggested that the biochemical characteristics of some foods mainly sweet-tasting foods might lead to presence of addiction behaviors, as withdrawal, loss of control, cravings of food in susceptible persons (52). Figure below (Fig 3) diagram showing sugar addiction.

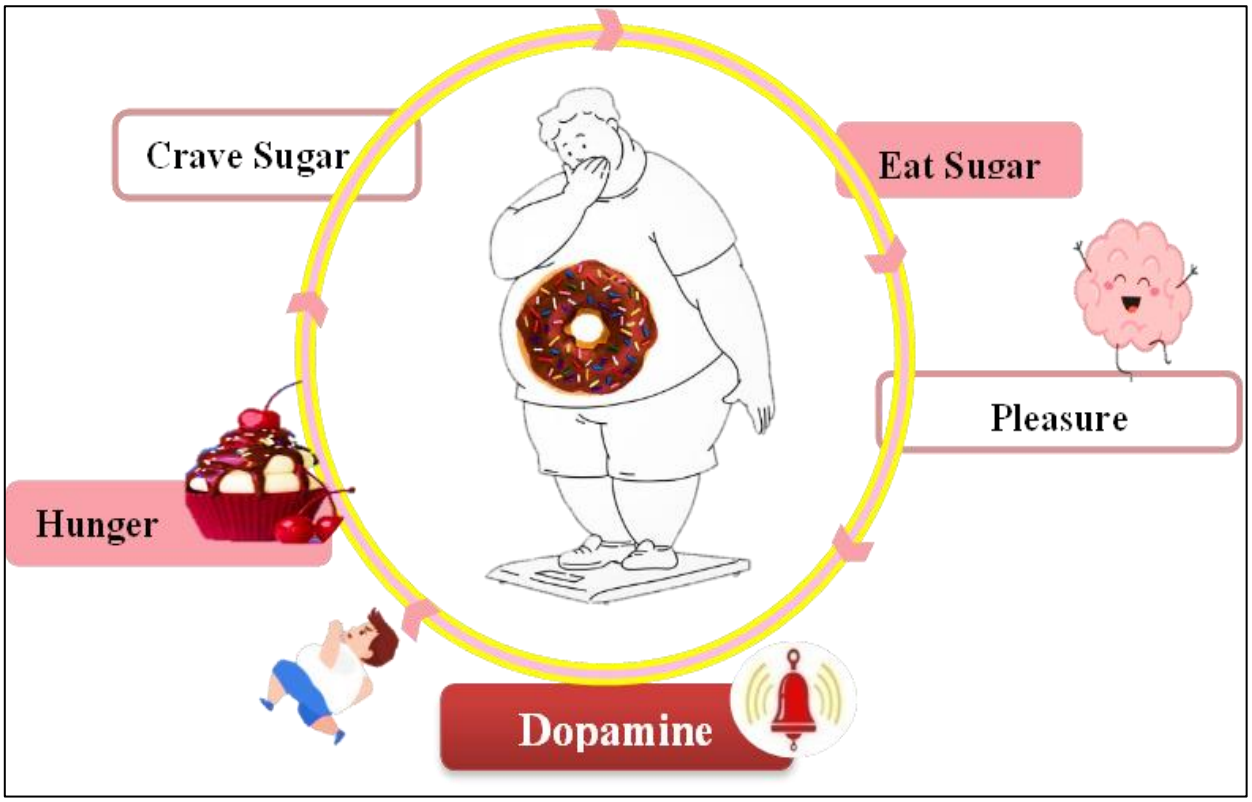

Figure (3): Sweet foods addiction. Over consuming sweet foods lead to: 1- Reward system activation, it stimulates release of dopamine, which associated with pleasureand thus reinforces behavior of consuming sweet foods. 2- Diminished Response: with time, regular intake of sweet foods could lead to a decreased dopamine response, (that's mean you be in need to intake more sweet foods to reach to the same level of the pleasure). 3- Cravings: The brain starts to demand from sugar. 4- Withdrawal Symptoms: When sweet foods intake is decreased or stopped, persons may feeling depression, fatigue, and headaches (designed by researcher using Microsoft Word 10).

CONCLUSION

This part consists of two (2) sub-parts: the article's conclusion and suggestions or recommendations from the research. Conclude the article critically and logically based on the research findings. Please be careful in generalizing the results. The authors should also state the research Food reward (not hunger) is the key driving potency behind food consumption in the present obesogenic environment, where that the reward helps in searching palatable foods that give energy and interesting taste, whose consumption is safe. However, sweet foods consumption, might leads to neuroadaptations in the reward system that prefers eating behavior over actual energy (calories) needs and thus causes the overeating.

Statement of Permission and Conflict of Interests

No conflict of interest is declared.

limitation in these parts. Generally, the conclusion should explain how the research has moved the body of scientific knowledge forward. In suggestion, please describe the author's recommendations for further studies regarding the author's research implication.

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