Mal J Nutr 17(2): 259 - 269, 2011

Review

Chocolate: Food for Moods

Wong SY& Lua PL

Centre for Clinical and Quality of Life Studies (CCQoLS), Faculty of Medicine and Health Sciences, Universiti Sultan ZainalAbidin (UniSZA), Kampus Kota ,20400 Kuala Terengganu, Terengganu, Malaysia

ABSTRACT

Introduction: Chocolate is a popular food and its consumption has long been associated with enjoyment and pleasure. The effect of chocolate on mood too has long been recognised. Chocolate is thought to have interactions with neurotransmitters which contribute to mood modulation and appetite regulation. However, the evidence in chocolate and mood studies remains highly controversial. As more is known about the influence of chocolate on mood, the reasons for these effects appear increasingly complex and inter-related. **Methods**: We reviewed chocolate's properties and the principal hypotheses addressing its mood altering propensities. **Results**: The relationship between chocolate and mood are highly complex, combining psychopharmacological components, nutritional and sensory characteristics of the food. Individual and situational differences on chocolate consumption may also exert influence on mood and the mixed results in previous research indicate that the direction of the association remains unclear. **Conclusion**: The association between chocolate consumption and emotions warrants further multi-prong investigations to substantiate chocolate's mood alterating propensity.

Keywords: Chocolate, mood, nutrients, oro-sensory aspects, pharmacological effects

INTRODUCTION

Chocolate is known as a unique psychoactive food which is produced from the seed of the tropical *Theobroma cacao* tree. Some people even believe that chocolate is the 'food of gods' as it appears to have been utilised as a medicinal remedy by leading physicians of the ancient days (Dillinger *et al.*, 2000). Yet, for the better part of the 20th century, consumption of chocolate has shifted from its medicinal purposes to being enjoyed as a confectionery. Chocolate is thought to have interactions with neurotransmitters which contribute to mood modulation and appetite regulation. The combination of chocolate's sensory characteristics, psychoactive components and nutrient composition may be the reasons why chocolate has become one of the most craved food worldwide. However, the evidence for chocolate and its influence on

* Correspondence author: Lua Pei Lin, Email: *peilinlua@unisza.edu.my*

mood remains highly debatable. We reviewed chocolate's pharmacological properties, nutritional components and orosensory aspects as well as the principal hypotheses addressing its claim on mood altering propensities.

PHARMACOLOGICAL CONSTITUENTS OF CHOCOLATE

One of the most clearly understood mechanisms through which chocolate can affect mood is through pharmacological reactions. Chocolate contains many psychoactive agents which may evoke psychophysiological sensations and may be the driving force for addiction or craving. Several biogenic amines with sympathomimetic characteristics have been identified in chocolate (Figure 1). Two unsaturated N-acylethanolamines unsaturated fatty acids that are found in chocolate are N-oleoylethanolamine and N-linoleoylethanolamine. These unsaturated N-acyltheanolamines in chocolate are the endogenous brain lipoprotein that binds to and activates cannabinoid receptors as the endogenous cannabinoid neurotransmitter or neuromodulator (Di Marzo *et al.*, 1998). These amines can mimic the functional effects of delta-9 tetra-hydrocannabinol (Δ 9_THC) such as heightened sensitivity and euphoria (Nocerino, Amato & Izzo, 2000).

Alkaloid methylxanthines represent a group of compounds that are found in chocolate, prominently caffeine (1,3,7-trimethylxathine) and theobromine (3,7-dimethylxanthine) (Meng, Mhd Jalil & Ismail, 2009). Both are stimulants which often cause relevant behavioural effects (Smit & Blackburn, 2005). According to Smit, Gaffan & Rogers (2004), caffeine and theobromine in combined amounts are found to be the psycho-pharmacologically active constituents of chocolate responsible for identical improvements on the mood construct 'energetic arousal' and cognitive function. This study in particular indicates

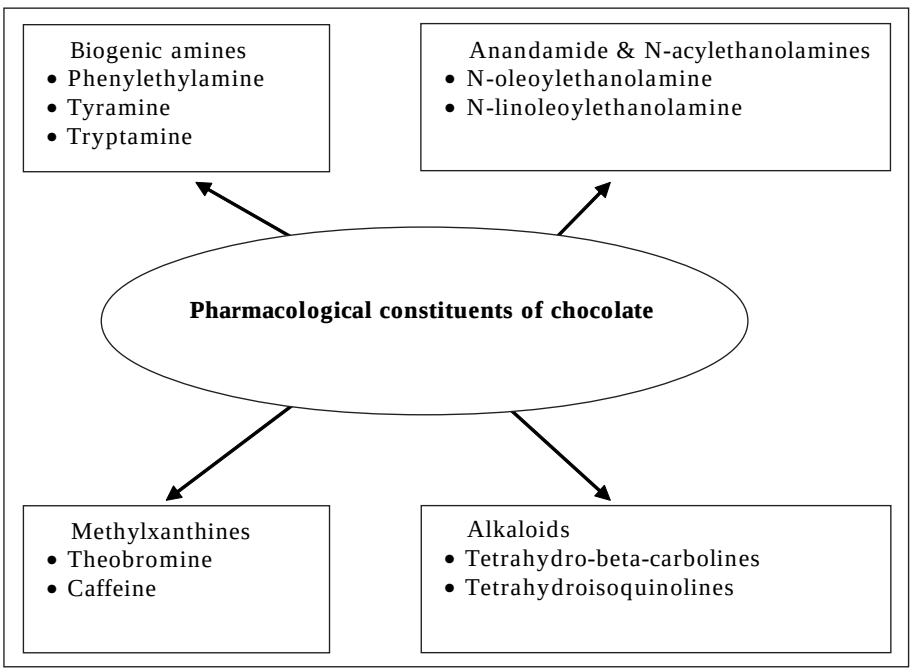

Figure 1. Pharmacological constituents of chocolate (adapted from Bruisma & Taren, 1999; Meng *et al.*, 2009; Nocerino *et al.*, 2000; Schroeder *et al.*, 2001; Taren & Morris, 2005).

that methylxanthines in chocolate provide psychostimulant effects, and that these effects are at the very least much greater in magnitude than those of any other potentially pharmacologically active constituents.

Two groups of alkaloids namely tetrahydro-beta-carbolines and tetrahydro-isoquinolines are alkaloid compounds present in chocolate which are also found in alcohol (Schroeder, Binzak & Kelley, 2001). These compounds have been found to exert neuroactive properties and have been related to alcoholism. However, no relationship between compulsive alcohol consumption and chocolate craving has been established. The tetrahydro-beta-carbolines appear to inhibit the action of monoamine oxidase (MAO), thereby increasing the effects of biogenic amines such phenylethylamine (PEA) and tryptamin, suppressing the breakdown of serotonin and dopamine and extending their duration of action (Herraiz, 2000). Salsolinol (SAL) and salsoline are the specific types of tetrahydroisoquinolines that are found in chocolate. SAL binds to dopamine receptors which are specifically responsible for reinforcement and reward. SAL may influence the production of endorphins and the amount of SAL ingested in 100g of chocolate is sufficient to interact with the dopamine receptors (Melzig *et al.,* 2000). The concentration of SAL in chocolate may be small but its effect on the brain is probably significant, especially in combination with the other biological stimulants of chocolate. Moreover, SAL has been deemed to be one of the main psychoactive compounds present in chocolate products. In addition, SAL has also been found to be associated with drug addiction.

Although some researchers claim that it is not possible for a low concentration of biogenic stimulants particularly anadamide and methyxanthines to create positive effects but many chocolate cravers still believe and claim that chocolates could help in improving a low mood. The association between chocolate consumption with particular drug-induced psychoses suggests that the psychopharmacologic influences of chocolate deserve further attention.

NUTRITIONAL COMPONENTS

Most chocolate studies have focused on the effects of chocolate consumption on mood due to its psychoactive components. Additionally, chocolate consumption has also been suggested to affect mood through its nutritional components. When referring to the carbohydrate-craving hypothesis, possibly the most extensively-investigated theory concerning nutritional influence of chocolate on mood is the relationship between carbohydrate contents, brain serotonin and depressed mood (Markus, 2002). The large amount of cocoa butter (fat) and sugar in chocolate has always caused confusion between chocolate preference and carbohydrate preference. The contents of sugars in chocolate have been reported to result in subsequent immediate increases of energy and alertness due to an increase in serotonin (Figure 2).

Serotonin plays an important role in influencing sleep, appetite, and impulse control and mood elevation by acting through a biofeedback mechanism to regulate carbohydrate consumption (Wolfe, Metzger & Stollar, 2008). High carbohydrate intake during chocolate consumption has been found to heighten the level of tryptophan in blood plasma. Once carbohydrates enter the bloodstream, they stimulate insulin production and facilitate the uptake of most amino acids, but exclude tryptophan uptake into the tissues. The proportion of circulating tryptophan increases relative to other amino acids, facilitating its passage across the blood–brain barrier, where it is converted into serotonin. As a result, mood may be elevated. Studies on seasonal affective disorder and atypical depression also support this

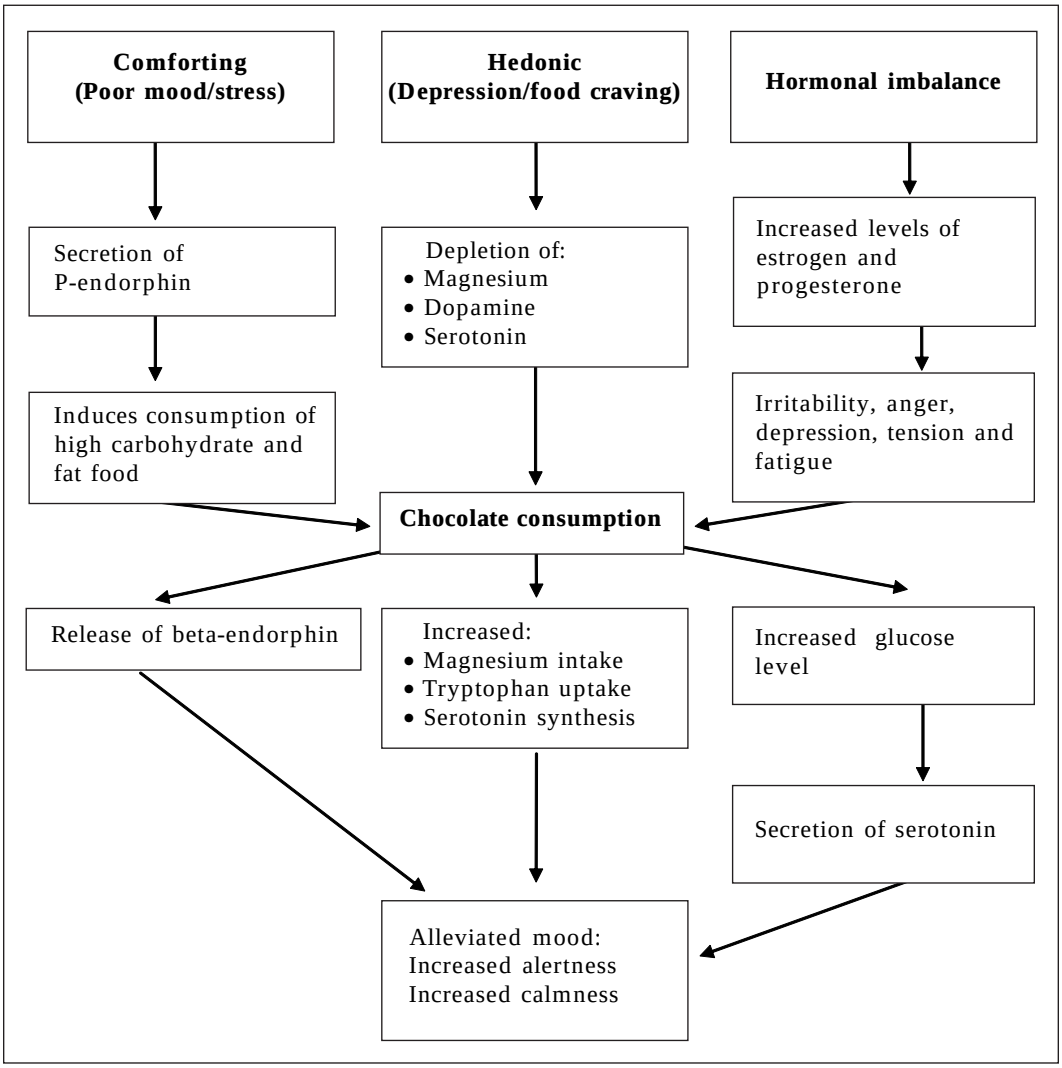

Figure 2. Chocolate consumption and mood alleviation (adapted from Benton, 2002; Christensen, 2001; Parker *et al.*, 2006).

hypothesis (Parker, Parker & Brotchie, 2006). In some depressed individuals, chocolate is consumed as a form of self-medication. In seasonal affective disorder, there is a disturbance of the feedback mechanism between serotonin and carbohydrate intake in which the desire for carbohydrates persists. Another appetite theory is that stress-prone individuals are similarly prone to serotonin deficiency; this is also related to chocolate craving as well as carbohydrate craving.

Stress commonly stimulates the secretion of mineral corticoids and glucocorticoids which results in a decrease in magnesium level in the body. Magnesium in lower levels can lead to selective depletion of dopamine (a neurotransmitter that transmits signal of satisfaction and euphoria in the central nervous system)

followed by a decrease in serotonin. Researchers have also discovered that magnesium deficiency tends to motivate chocolate consumption particularly in premenstrual syndrome (PMS). The high concentration of magnesium (520mg / 100g) in chocolate is proposed to elevate mood (Bruinsma & Taren, 1999). The hormonal concert of changes during stress creates a cascade of biochemical and physiological events that require energy and nutrients.

Depending on the individuals, stress can either increase or decrease appetite (Christensen, 2001). It has been suggested that the use of chocolate by some women as a form of self-medication is intended to balance the low levels of neurotransmitters involved in mood regulation such as serotonin and endorphin (Figure 2). Interestingly, the desire for chocolate by females fluctuates with hormonal changes and is higher just before and during their menses (Hormes & Rozin, 2009). This hormonal association in turn might be related to endogenous opiates (endorphins) which influence appetite. Generally, ladies tend to consume food when feeling emotionally low, and the affinity to chocolate may due to the psychoactive components that remain elusive.

ORO-SENSORY ASPECTS

The ingestion of food in the mouth is stimulatory, while the entry of food into the stomach is inhibitory. Interestingly, the most acceptable explanation for chocolate craving focuses on its oro-sensory properties which are mediated by its palatability and its unique combination of sweetness, taste, and texture. Moreover, palatability is determined by innate responses such as the human taste preference for sweetness but not for bitter tastes (Scott, 2005). Apart from caffeinated drinks, most food consumed in order to alter mood are highly palatable particularly chocolate. The sweet taste in chocolate is known to be innately pleasing and highly preferred. The texture of fat or the creamy taste of chocolate is similarly thought to be a positive factor and with the combined action of sensuous feeling of melting cocoa butter in the mouth, it is not surprising that chocolate has emerged as one of the most highly-craved foods. These effects are considered to be sensory rather than nutritional due to the negligible amount of nutrition required to produce an effect. Furthermore, reviews have also supported the belief that the oro-sensory properties of chocolate and the desire for sensory gratification are sufficient to explain the motivation for eating chocolate, and that the sight and aroma of chocolate is adequate to trigger cravings (Parker *et al.*, 2006).

While the sensory aspects of chocolate may be essential for the effects of foods on mood, nutritional and psychoactive constituents do still have important roles. It has been suggested that chocolate can impose effects on mood simply by providing a pleasurable experience, possibly mediated through the release of endorphins. Endorphins are chemically similar to morphine and these opiates are responsible for the body's response to pleasure, stress, pain and addictions. It is now believed that cravings for sweet and high-caloric foods such as chocolate may be partly mediated by endorphins (Schenker, 2000). Moreover, chocolate is a highly palatable food as it contains at least 50% fat and almost 50% carbohydrate (Schenker, 2000). As a palatable food, chocolate consumption similarly stimulates the release of endorphins which produce the feel-good sensation and may even increase appetite. If the sensory experience is mediated by brain opiates, rather than chocolate's drug-like constituents, then only chocolate itself should satisfy the craving.

Investigations utilising white chocolate are useful in delineating the extent to which the sensory qualities of chocolate contribute to cravings. White chocolate possess similar texture and sweetness of chocolate due to

the sugar and cocoa butter contents. However, it does not emit chocolate's distinctive aroma and does not generate the pharmacological effects (no cocoa liquor). Hence, white chocolate consumption only produced the intermediate effect of reducing craving (Taren & Morris, 2005). These also lend credence to either a notable sensory or pharmacological effect of chocolate. The composite oro-sensory properties of chocolate undoubtedly outweigh the more simple explanations of its role in appetite and satiety. In addition, if psychoactive substances are responsible for craving, then the unsweetened cocoa powder should have an equal appeal, and other foods containing these substances in higher concentrations should be craved, but in reality they are not. Chocolate is craved because of its hedonic experience, which is the result of a set of an appealing set of characteristics, an attractive aroma, and a unique sensory combination of chocolate flavour. Therefore, according to Visioli and co-investigators, chocolate is consumed simply because "it tastes so nice" (Visioli *et al.,* 2009).

INDIVIDUAL CHARACTERISTICS

If the effects of chocolate on mood result from the pharmacological, nutritional and sensory aspects, it stands to reason that individual responses to chocolate will be different. Many individuals will crave for chocolate in order to alleviate low mood; others will reach out for high caloric food such as ice-cream. For instance, the carbohydrate and chocolate cravers were significantly less depressed after snacking, whereas non-cravers experienced negative effects such as fatigue and sleepiness. These findings suggest that both the carbohydrate and chocolate cravers prefer food in such a manner in order to restore flagging vitality (Taren & Moris, 2005). In addition, some individuals, for example, will gulp a cup of coffee when their energy level or attention span is deteriorating. But those sensitive to caffeine will not experience similar positive effects on mood. In contrast, they will probably experience nothing or mood deterioration instead. Similar effects are also found for alcohol and a variety of other food components (Rogers & Dernoncourt, 1998). More obviously, every individual has a personal preference for certain types of foods. These differences between individuals depend on personal tastes, attitudes, beliefs and previous experiences (Solomon, 2001). Foods which are considered harmful to an individual will not result in mood improvement but lead to deterioration in mood. Commonly this situation can be observed in individuals on a weight-loss diet who consume highly preferred food to enhance good mood. Ironically, ingestion of preferred food among weight-loss dieters will lead to an overriding deterioration in moods as a result of the guilt, anxiety and feeling of failure (Christensen & Pettijohn, 2001). Learning based on previous experiences is also thought to determine much of future experience, and the effects of food on mood are no exception. Consequently, the continual learning, attitudes and beliefs can vary over time, allowing those effects to develop and change.

SITUATIONAL/CONTEXTUAL VARIABLES

The effects of food on mood are also influenced by contextual or situational variables particularly emotional eating. Many factors influence the desire to eat a particular food because food preference is altered across a range of emotional states. Besides psychological or physiological state, the availability of certain foods and the pleasure derived from food consumption could also determine the desire for consumption of a particular food. In negative mood states, the preference for junk food such as chocolate is usually increased. In contrast, the preference for healthy food increases only during a positive mood state.

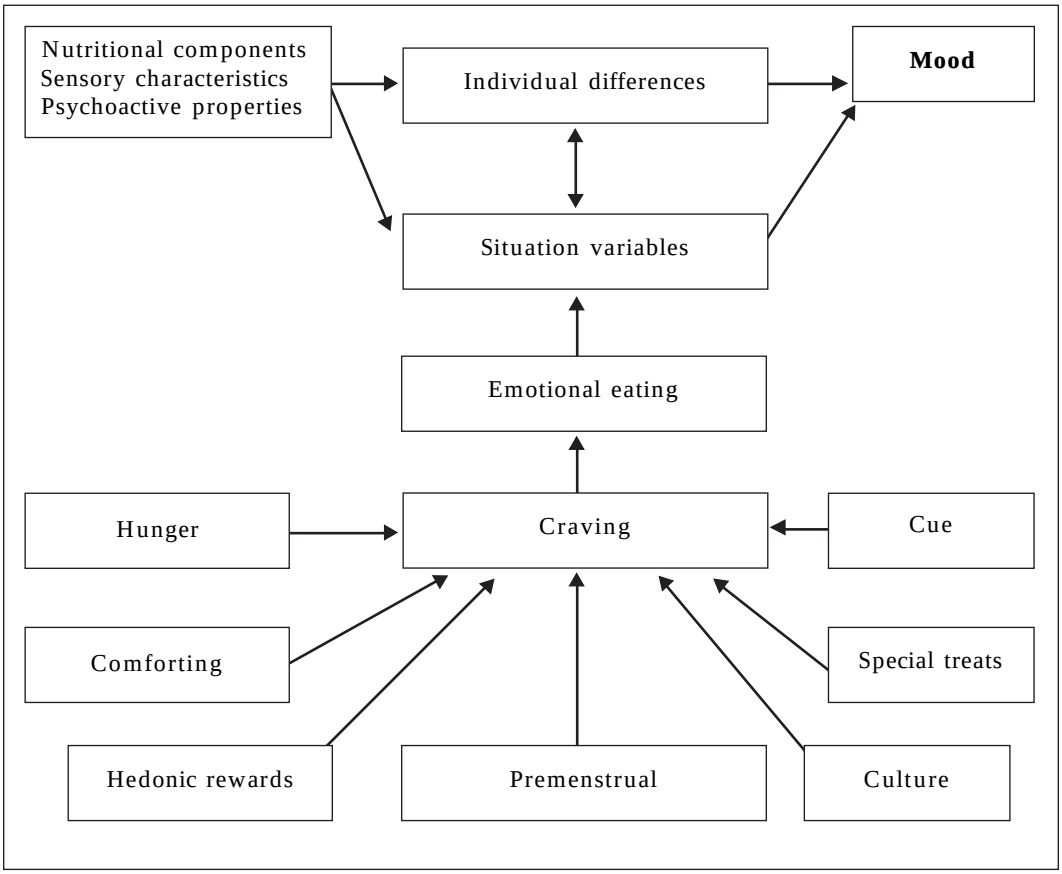

Figure 3. Chocolate consumption and mood (adapted from Benton, 2002; Bruisma & Taren, 1999; Christensen, 2001; Rogers & Smit, 2000; Parker *et al.*, 2006).

For example, consumption of chocolate causes an increase in alertness and energy among depressed chocolate cravers (Figure 3). Alternatively, those who ingest chocolate after successful dieting may experience extreme improvement of mood. Conversely, those who have been through a week of unsuccessful dieting are more likely to experience a worsening of mood (Solomon, 2001).

Another example of food's effects on mood would be the heightening of happiness and contentment among women following chocolate consumption at particular times which are thought to be partly attributed to the circulating menstrual hormones or low mood states (Zellner *et al.*, 1999). Stress-associated chocolate eating is more common in chocolate lovers but the mixed results in research indicate that the direction of the association remains unclear. Such association depends on the current emotional state of the individuals. In carbohydrate craving, such hypothesis is not supported. In view of chocolate's close association to craving, it is consequently vital to dissect this issue from a scientific point of view.

Food craving incidentally shares some features with drug addiction, including similar neurotransmitter substrates and terms such as 'chocoholic' and 'carbohydrate craving' are commonly used, but there is no consensus that food craving qualifies as an

addiction. The concept of food and chocolate craving remains diverse and controversial. Chocolate craving is even more problematic in the context of food as it is a food that is not made from one substance but comprises many different nutrients. Chocolate may evoke similar psychopharmacological and behavioural reactions in susceptible persons (Bruisma & Taren, 1999).

Generally, chocolate craving is extremely common in Western countries and is closely associated with liking, since chocolate is highly palatable and represents one of the most-commonly-craved foods (Pelchat, 2002). Nonetheless, chocolate craving is not synonymous with an increase in consumption. Similarly, hunger is not the initial state for craving. Instead, there are stronger links between mood and craving. In the context of emotional eating, chocolate craving may co-exist with carbohydrate craving in the same individuals. The chocolate craving phenomena is also claimed to be driven by the desire for hedonic rewards and dopamine is the predominant neurotransmitter released after pleasurable chocolate consumption (Koob & Le Moal, 2001). In contrast, in carbohydrate craving mood alleviation is motivated by the purpose of comforting through endorphin production (Parker *et al.*, 2006).

Craving for chocolate is found to be stronger and to disappear much more slowly than craving for other sweet or savoury foods. For most chocolate cravers, non-chocolate substitutes are not sufficient to replace chocolate. According to this claim, even foods which have the same psychoactive properties appear not to satisfy chocolate craving. The phenomena of chocolate craving could be explained by physiological event or changes that cause craving and the caloric effects or the pharmacological effect that satisfies craving through chocolate ingestion. Although these claims are likely to be empirically associated, they are logically independent. Michener & Rozin (1994) have provided experimental evidence that the sensory properties of chocolate are the more acceptable reason that satisfies chocolate craving. According to the study, when chocolate is consumed in capsule form, findings immediately shed doubt on the physiological route of chocolate craving as the capsules are not able to satisfy the cravers (Visioli*et al.*, 2009).

In the context of hunger, chocolate craving can be defined as the expression of a learned appetite. According to a study on chocolate craving and hunger state, chocolate craving seemed to increase or be established by the repeated experience of chocolate consumption during hunger. In contrast, when chocolate is eaten repeatedly only when satiated, craving is substantially reduced among the cravers (Gibson & Desmond, 1999). Based on the findings of a previous study, craving for chocolate is then suggested to be an expression of a strong appetite elicited by hunger which has been acquired through repeated experience (learning) of the craved food when hungry.

The other causes of chocolate craving may be the result of culture. Studies suggest that culture determines not only what we crave but also when we crave (Zellner *et al.*, 1999). Chocolates are snack foods eaten at times other than at mealtime and is a habit influenced by the individual's culture. For example, chocolate is consumed after eating or when studying by Spanish women (Zellner *et al.*, 2004). Zellner *et al.* (1999) also discovered that chocolate craving is much less common in Spanish women (16.7%) than in American women (27.8%) despite its high per capita intake in both cultures.

Cues such as images, smells, and emotions related with chocolate activate similar brain regions and neural circuitries as those activated following exposure to drug-associated cues (Schroeder *et al.*, 2001). Studies involving brain scans found that brain areas such as the orbitofrontal cortex, the pregenual cingulate cortex and ventral striatum are activated more by the sight, smell, taste and texture of chocolate in

cravers. The activation in these regions is related to the pleasantness of food (Small *et al.*, 2001; Wang *et al.*, 2004). Studies have also provided neurobiological evidence that it is these brain systems that react strongly to the rewarding properties of a craved food (chocolate) in cravers (Small *et al.*, 2001). The cues present when chocolate is eaten become linked with chocolate, triggering a craving for chocolate on future occasions (Zellner *et al.*, 2004).

Chocolate consumption is generally one form of major mood-regulatory self-gift device in modern western societies. Not surprisingly, chocolate craving also possibly resulted from similar perceptual properties of chocolate which functioned as 'special treat' (Zellner *et al.*, 2004). Chocolate is one of the common things that consumers buy when in a bad mood (Luomala & Laaksonen, 1999). In relation to sensory aspects, chocolate does exert oral hedonic enjoyment which can act as a self-medication and pain-killer. However, in mood-maintaining self-gift behaviours, these expectations are not as precise. The success of chocolate as a self-gift is influenced positively by the satisfaction ratings of the chocolate products acquired as self-gifts and stores in which these activities are pursued.

For chocolate cravers, chocolate possesses the ability of being 'overpowering,' 'preying on my mind,' 'you cannot take it or leave it' and 'can't get it out of my head.' The question of why people crave for chocolate has also been addressed in scientific research; but much of these has been largely speculative and relatively little empirical studies have actually been carried out. Somehow, it is clear that chocolate consumption can have a significant influence on mood, generally leading to an increase in a good feeling and a reduction in tension, although guilt may be a penalty for some individuals (Christensen & Pettijohn, 2001). Also, craving for chocolate is related to negative moods (e.g. boredom, dsyphoria, depression and fatigue) (Macht & Dettmer, 2006). Chocolate is not addressed as a drug but is curiously as a food that possesses the properties of a drug. It is clear that chocolate can have neurologic effects because it will induce migraine in certain individuals (Ross, 2007). The chemical substances in chocolate may react with the neuro-transmitters as well as affect the central nervous system and result in behavioral changes and often cause craving or addiction.

CONCLUSION

The relationship between chocolate and mood is highly complex, involving psychopharmacological components, nutritional and sensory characteristics of the food. Furthermore, individual and situational differences in chocolate consumption may exert an influence on the mood. Mixed results of past research indicate that the association between chocolate eating and mood remain unclear. While the pharmacological, nutritional and sensory properties of foods may determine their effects on mood up to a point, individual and situational characteristics also appear to play important roles. Discrepancies in current research are also rather expected. However, there is progress both in relation to the description of effects of chocolate on mood and in understanding the mechanisms underlying these effects. In the future, behavioural studies in chocolate consumption should be implemented alongside biophysiology, neuropharmacology and quality of life outcome investigations in human beings.

REFERENCES

Benton D (2002). Carbohydrate ingestion, blood glucose and mood. *Neuro sci Biobehav R* 26: 293–308.

Bruinsma K & Taren DL (1999). Chocolate: food or drugs? *J Am Diet* 99: 1249–256.

Christensen L (2001). The effect of food intake on mood. *Clin Nutr* 20(1): 161–166.

Christensen L & Pettijohn L (2001). Mood and carbohydrate cravings. *Appetite* 36: 137–45.

Dillinger TL, Barriga P, Escarcega S, Jimenez M, Salazar Lowe D & Grivetti LE (2000). Food of the gods: cure for humanity? A cultural history of the medicinal and ritual use of chocolate. *J Nutr* 130: 2057S–2072S.

Di Marzo V, Sepe N, De Petrocellis L, Berger A, Crozier G, Fride E *et al.* (1998). Trick or treat from food endocannabinoids? *Nature* 396: 636.

Gibson EL & Desmond E (1999). Chocolate craving and hunger state: implications for acquisition and expression of appetite and food choice. *Appetite* 32: 219–240.

Herraiz T (2000). Tetrahydro-beta-carbolines, potential neuroactive alkaloids, in chocolate and cocoa. *J Agr Food Chem* 48: 4900–4904.

Hormes JM & Rozin P (2009). Perimenstrual chocolate craving. What happens after menopause? *Appetite* 53: 256–259.

Koob GF & Le Moal M (2001). Drug addition, dysregulation of reward, and allostasis. *Neuropharmacology* 24: 97–129.

Luomala HT & Laaksonen M (1999). A qualitative exploration of mood-regulatory self-gift behaviours. *J Econ Psychol* 20: 147–182.

Macht M & Dettmer D (2006). Everyday mood and emotions after eating a chocolate bar or an apple. *Appetite* 46: 332–336.

Markus CR (2002). New insight in the beneficial effects of food on mood and performance: evidence for interference between stress and brain 5-HT. *Agro Food Industry Hi-Tech* 13(5): 21–23.

Meng CC, Mhd Jalil AM & Ismail A (2009). Phenolic and theobromine contents of commercial dark, milk and white chocolates on the Malaysian Market. *Molecules* 14: 200–209.

Melzig MF, Putscher I, Henklein P & Haber H (2000). *In vitro* pharmacological activity of the tetrahydroisoquinolinesalsolinol present in products from *Theobroma cacao* L. like cocoa and chocolate. *J Ethnopharmacol* 73: 153–159.

Michener W & Rozin P (1994). Pharmacological versus sensory factors in the satiation of chocolate craving. *Physiol Behav* 56: 419– 422.

Nocerine E, Amato M & Izzo AA (2000). Cannabis and cannabinoid receptors. *Fitoterapia*, 71: S6–S12.

Parker G, Parker I & Brotchie H (2006). Mood state effects of chocolate. *J Affect Disorders* 92: 149–159.

Pelchat ML (2002). Of human bondage: food craving, obsession, compulsion, and addiction. *Physiol Behav* 76: 347–352.

Ross SM (2007). Chocolate: be bad to feel good. *Holistic Nursing Practice* 21(1): 50–51.

Rogers PJ & Dernoncourt C (1998). Regular caffeine consumption: a balance of adverse and beneficial effects for mood and psychomotor performance. *Pharmacol Biochem Be* 59: 1039–45.

Rogers PJ & Smit HJ (2000). Food craving and food 'addiction': a critical review of the evidence from a biopsychosocial perspective. *Pharmacol Biochem Be* 66: 3–14.

Scott K (2005). Taste recognition: food for thought. *Neuron* 48: 455–64.

Smit HJ & Blackburn RJ (2005). Reinforcing effects of caffeine and theobromine as found in chocolate. *Psychopharmacology* 181: 101–106.

Smit HJ, Gaffan EA & Rogers PJ (2004). Methylxanthines are the psycho-pharmacologically active constituents of chocolate. *Psychopharmacology* 176: 412–419.

Schenker S (2000). Review: The nutritional and physiological properties of chocolate. *British Nutritional Foundation* 25: 303–313.

Schroeder BE, Binzak JM & Kelley AE (2001). A common profile of prefrontal cortical activation following exposure to nicotine- or chocolate-associated contextual cues. *Neuroscience* 105: 535–545.

Small DM, Zatoree RJ, Dagher A, Evans AC & Jones-Gotman M (2001). Changes in brain activity related to eating chocolate: from pleasure to aversion. *Brain* 124: 1720–1733.

Solomon MR (2001). Eating as both coping and stressor in overweight control. *J Adv Nurs* 36: 563–72.

Taren D & Morris K (2005). Karger Gazette. *Chocolate* 68: 7–8.

Wang GJ, Volkow ND, Telang F, Jayne M, Ma J *et al.* (2004). Exposure to appetitive food stimuli markedly activates the human brain. *Neuroimage* 21: 1790–1797.

Wolfe BE, Metzger ED & Stollar C (2008). Neurobiology of anorexia and bulimia nervosa. *Physiol Behav* 94: 121–135.

Visioli F, Bernaert H, Corti R, Ferri C, Heptinstall S, Molinari E *et al.* (2009). Chocolate, lifestyle, and health. *Crit Rev Food Sci* 49: 299–312.

Zellner DA, Garriga-Trillo A, Centeno S & Wadsworth E (2004). Chocolate craving and the menstrual cycle. *Appetite* 42: 119–121.

Zellner DA, Garriga-Trillo A, Rohm E, Centeno S & Parker S (1999). Food liking and craving: a cross-cultural approach. *Appetite* 33: 61–70.