

## Is Chocolate the Ultimate Comfort Food?

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### ABSTRACT

Since a long time, we know the physiological effects of methylxanthines that they are mediated by the so-called adenosine receptors. Caffeine and theobromine are the commonly seen methylxanthines in cocoa with notable physiological effects. Due to numerous health-promoting benefits, chocolate is being explored as a functional food by food researchers. This is a systematic review conducted to evaluate the benefits of chocolate on the mood and cognitive functions. Cocoa, now is used as a confectionary by the chocolate industries around the world, while in the past this was more like a medicinal use. Neuromodulatory and neuroprotective actions of cocoa flavanols in humans have been discussed.

**Keywords:** Blood pressure; chocolate; cocoa; flavanols.

### INTRODUCTION

Cocoa products with epicatechin increased flow-mediated vasodilatation (FMD). Cocoa flavanol 900 mg and above reduced blood pressure in some subjects. Out of 32 cocoa product samples, two food supplements had 900 mg of total flavanols and 100 mg epicatechin. Hence the study suggests that the chocolate products marketed with health benefits must declare the content of total flavanols and epicatechin.<sup>1</sup> According to the C-FFQ questionnaire used by Vicente F1, Saldaña-Ruiz S et al., 2016., chocolate bars were the critical source of cocoa among university students, also the dairy products gave an important amount of cocoa.<sup>2</sup> Chocolate milk was the choice of schoolchildren over to plain milk even if when a reduced-sugar formula was used. A low sugar chocolate milk led to a alleviation in the number of students choosing milk. Study need to be done to determine whether students would purchase reduced-sugar chocolate milk at equal rate as they would purchase regular chocolate milk.<sup>3</sup> Flavanol-rich chocolate attenuated the vascular impairment due to sleep deprivation thus restoring the working memory performance. Cognitive performance was improved may be due to beneficial effect of cocoa flavonoids on blood flow and blood pressure.<sup>4</sup> Chocolate consumption was associated with enhanced performance on the

Global Composite score, Visual-Spatial Memory and Organization, Scanning and Tracking, Working Memory, Abstract Reasoning, and the Mini-Mental State Examination. Hence relation to the cognitive performance, measured with an extensive battery of neuropsychological tests.<sup>5</sup> Dark Chocolate (DC) reduced the hyperglycemia. There was inhibition of cholinesterase activity in the hippocampal tissue homogenates, but improvement in the cognitive performance of spatial memory related Barnes maze task. An increase in cell volume was found in the DC treated rats in the CA3 region of the hippocampus in the histological studies. Findings revealed the usefulness of DC to enhance cognitive function and cholinergic activity in the hippocampus of the aged NTAD rats.<sup>6</sup> Beneficial effect of dark chocolate was noticed on blood pressure, lipids, and inflammation. Probable mechanisms of benefits might be due to enhanced nitric oxide bioavailability and improved mitochondrial structure and function.<sup>7</sup> Literature review asserted that some cocoa products do favorable effect on human health at various stages of life. Women were more favored by consumption of cocoa products. Hence chocolate with specific features might become a supplementary source of energy for pregnant woman.<sup>8</sup> Intervention studies on healthy and

metabolically-dysfunctional volunteers showed the beneficial effect of cocoa in improving the blood pressure, platelet aggregation and endothelial function. Sucrose and lipid had a transient and negative impact on endothelial function, partly through insulin signalling and nitric oxide bioavailability, thus making the chocolate effect to be more convoluted.<sup>9</sup>

The study done by Mellor DD<sup>1,2,3,4</sup>, Sathyapalan T et al., 2015., indicated that the past published research reports were varying in quality, poor selection of controls and also inadequate blinding procedures. Inconsistencies were noted in the reporting of data with limited information on the effects of cocoa and chocolate supplementation in controlling the weight and glycemic levels in spite of the potential benefits of the cardiovascular risk factors of endothelial function and lipids.<sup>10</sup> Theobromine, found in bigger amounts than caffeine, lies behind several effects featured to cocoa intake. Chief mechanism of action were inhibition of phosphodiesterases and blockade of adenosine receptors. Hence the , theobromine forms a critical part of the most attractive molecules in cocoa.<sup>11</sup> Dietary interventional research done by Mastroiacovo D, Kwik-Urbe C et al., 2015., indicated that regular cocoa flavanols (CF) consumption reduced age-related cognitive dysfunction, probably by means of improvement in insulin sensitivity. Hence suggesting that the habitual intake of flavanols favours healthy cognitive function with aging.<sup>12</sup>

Past meta-analyses suggested beneficial effects of chocolate in cardiac metabolism following short-term intake. Also improvements were shown in flow-mediated dilatation, blood pressure, biomarkers of insulin resistance and lipoprotein levels. Flavan-3-ols had a critical role, but not explicit on what specific compounds or metabolites were critical. Theobromine improved lipoprotein levels among subjects in trial studies but still need verification at habitual intake levels.<sup>13</sup> Among the healthy volunteers aged 47-69 years old who were assigned randomly a 28-day oral intake of different dark chocolate (DC) formulations, proprietary lycopene-containing (L-tug) lycopene formulation of DC with enhanced bioavailability of cocoa flavanols was more efficient in reducing diastolic blood pressure. Serum high-density lipoprotein (HDL) cholesterol, C-reactive protein (CRP) and glucose level values were unchanged.<sup>14</sup> Study done by von Känel R, Meister RE et al., 2014., revealed that a single consumption of flavonoid-rich dark chocolate reduced the acute prothrombotic response to psychosocial stress, thus by mitigating the risk of acute coronary syndromes initiated by emotional stress.<sup>15</sup> Daily intake of dark chocolate with >75% cocoa during a period of one month alleviated vascular function in young and healthy individuals. The study was done in 60 healthy volunteers using Blood pressure (BP), flow-mediated dilation (FMD), aortic pulse wave velocity (PWV), arterial stiffness index (ASI), and pulse wave analysis (PWA).<sup>16</sup>

Sensory pleasure to tongue

Soothes a bad mood

Contains caffeine that raises stomach acid levels

Natural calming effect

Appetite suppression

Small reduction in blood pressure

Decrease in LDL cholesterol

Improves brain power and memory

Fig. 1: Benefits of chocolate on human health

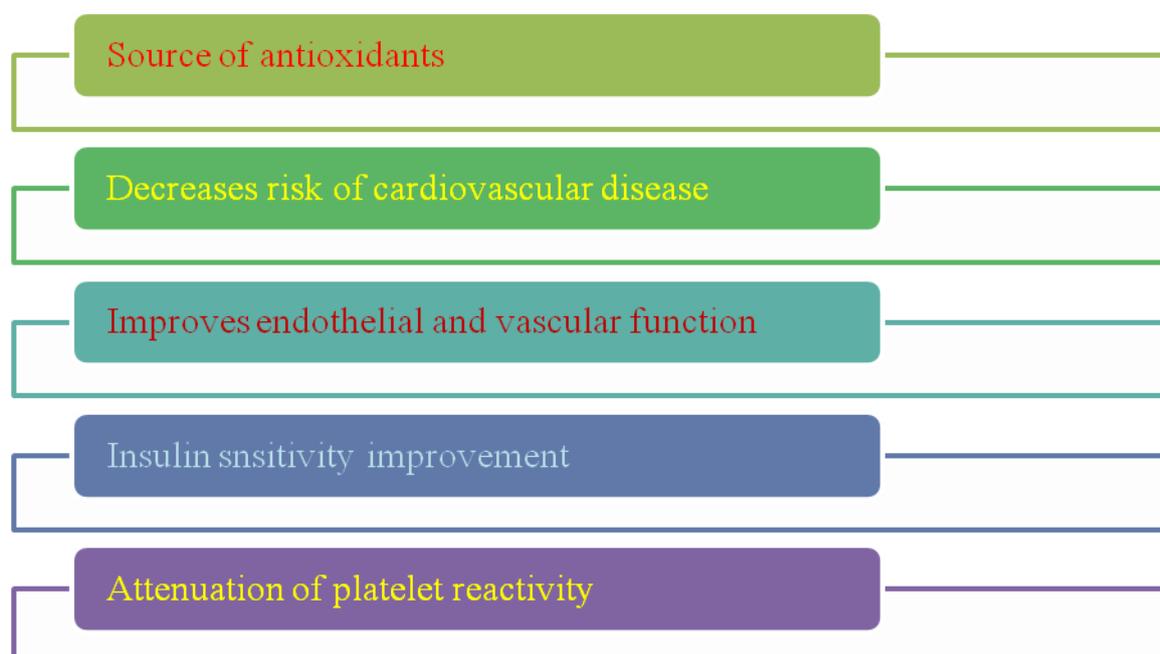
Elimination of chocolate milk inside school cafeterias attenuated calorie and sugar consumption. This also made students to consume less milk overall, waste more of the white milk they take, and not purchase school lunch any more. Hence the food service managers must vigilantly weigh the costs and benefits of eliminating chocolate milk. Must consider other options to make white milk more convenient and normal choice.<sup>17</sup> Flavanols and theobromine, contributed to enhancements in endothelial function and subsequent improvements in cardiovascular disease (CVD) including hypertension, platelet aggregation and adhesion, hypercholesterolemia and insulin resistance.<sup>18</sup> Review study done by Mogollon JA, Boivin C et al., 2013., elucidated on the information regarding the plausible relation between chocolate consumption and avoiding of preeclampsia. Hence the justification whether any additional experimental trials were needed for evaluation of the beneficial effects of chocolate consumption on the risk of preeclampsia. Validity of the studies were appreciated by using Cochrane Collaboration's tool.<sup>19</sup> Molecular dynamics (MD) simulations aided in understanding the complex and multi-component food systems. MD simulations gave multiple benefits to researchers in verification of their hypothesis in dynamic simulations with an atomistic resolution.<sup>20</sup> Flavanol fortification affected the taste and negatively affected motivation to consume chocolate. Study done by Esser D, Mars M et al., 2014., revealed on how chocolate affects endothelial health by showing that chocolate consumption improves vascular function and attenuates the adherence capacity of circulating leukocytes.<sup>21</sup> Caffeine and theobromine are the critical methylxanthines in cacao with noted physiological effects. Chocolate is considered as a functional food, because of remarkable health-promoting benefits. Adenosine receptor blockade by natural compounds present in cacao/chocolate has got some consequences. Health benefits and palatability of methylxanthines and theobromine, specifically, have contributed enough for sustaining a pleasant habit of chocolate consumption.<sup>22</sup> Studies did not show any behavioral benefits due to chocolate eating, but identified alterations in brain activation patterns. It was indistinct if the effects of chocolate on mood were because of orosensory characteristics of chocolate or else due to the pharmacological actions of chocolate constituents. Acute cognitive effects of supplementation with cocoa polyphenols were revealed.<sup>23</sup> Cocoa

attenuates body weight by enhancing mitochondrial biogenesis. Increases muscle glucose uptake by inserting glucose transporter 4 into the membranes of skeletal muscle cells. Antioxidant properties of cocoa gives protection for neurons and improves the cognition and positive mood. Reduction in the immunoglobulin E release occurs during allergic responses with usage of chocolate. It also affects the immune response and bacterial growth in intestines. Reduction in the inflammation process happened by inhibiting nuclear factor- $\kappa$ B.<sup>24</sup>

Neurobiological action of flavanols in cocoa occurred by two ways: (a) direct interactions among cellular cascades with expression of neuroprotective and neuromodulatory proteins to promote neurogenesis, brain connectivity and neuronal function, and (b) improvement of blood-flow and angiogenesis in the brain sensory systems. Shielding effect of flavanol consumption (long-term) on neurocognition and behavior, effect on age and disease-related cognitive decline, were demonstrated in the animal models of normal aging, dementia, and stroke.<sup>25</sup> Separation of Dietetics from Medicine, aided chocolate to acquire function to ease the administration of bitter medications, for diverse health problems. With the rediscovery of beneficial application of cacao and chocolate, value has been added to chocolate as a supplemental nutrition.<sup>26</sup> Epicatechin affected the synthesis of nitric oxide and breakdown through inhibition of nicotinamide adenine di-nucleotide phosphate oxidase. Inhibited the substrate arginine by attenuation of arginase, among other targets. This indicated cocoa as a biologically active ingredient having critical benefits on biomarkers in cardiovascular diseases. Calorie and sugar content of chocolate and its contribution to the total diet has to be taken into consideration for interventional studies.<sup>27</sup> Past research scholars criticized chocolate for high fat content and so frequent consumption was avoided. Associated with acne, caries, high blood pressure, obesity, coronary artery disease and diabetes. But, recent discovery of biologically active phenolic compounds in cocoa has altered this old perception and encouraged research on the beneficial effects on ageing, blood pressure regulation, atherosclerosis and oxidative stress.<sup>28</sup> Cocoa autolysates contained plenty of hydrophobic amino acids. The research done by Sarmadi B, Aminuddin F et al., 2012., indicated that besides other compounds of cocoa, its peptide contents and amino acids contributed to health benefits.<sup>29</sup> Eating cocoa flavanols regularly, aided in improvement of

cognitive function in the elderly individuals having some degree of cognitive impairment. This beneficial effect could have been

mediated by an alleviation of insulin sensitivity.<sup>30</sup>



**Fig. 2: Benefits of cocoa**

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) reduced after 4 weeks of consumption of polyphenol-rich dark chocolate (DC). Placebo raised fasting insulin, homeostasis model assessment of insulin resistance (HOMA-IR) and salivary cortisol, this effect was dissimilar to polyphenol-rich DC that showed a little effect on fasting insulin, HOMA-IR and salivary cortisol.<sup>31</sup> Ginseng extract tasted as sweeter, starchier, and more green tea over when compared to the other sample solutions. Such features of this ginseng extract were altered by the addition of caffeine, cyclo (L-Pro-L-Val), and 2 model solutions that contained dark chocolate extracts. Adding of ginseng extract alleviated the duration time in specific bitterness of the 2 model solutions. Bitter compounds found in dark chocolate effectively masked the unique flavors of ginseng.<sup>32</sup> Effects of chocolate, cocoa, and flavan-3-ols on major cardiovascular disease risk factors were investigated. The review study done by Hooper L, Kay C et al., 2012., found that chocolate or cocoa had consistent benefits on Flow-mediated dilatation (FMD) and promising effects on insulin and HOMA-IR. Even then the larger, longer-duration trials were needed to confirm the potential cardiovascular benefits of

cocoa flavan-3-ols.<sup>33</sup> Post exercise consumption of fat-free chocolate milk (MILK) resulted in greater mixed muscle fractional synthetic rate (FSR) with lesser whole-body proteolysis and synthesis than with control beverage. Hence the effects of consumption of MILK after endurance exercise on FSR, leucine kinetics, signaling molecules of skeletal muscle protein turnover, and performance measures indicate the beneficial effects of milk compared with a nonnitrogenous isocaloric carbohydrate only beverage.<sup>34</sup>

Dark chocolate showed high levels of total flavanols than a white chocolate. The quantity and integrity of procyanidins often differ in the chocolate manufacturing, mainly due to oxidation and alkalization reactions. In the study done by Langer S, Marshall LJ et al., 2011, the labeled cocoa content of the chocolate not all the time reflected the presumed levels of flavonoids analyzed before.<sup>35</sup> Consumption of chocolate played an important role in the defending modulation of blood pressure, the lipid profile, the sensitivity to insulin and the activation of platelets. Dark chocolate showed more protective effect than the milk or white chocolate. Still the well defined clinical studies were not yet available

in the data bases.<sup>36</sup> Cocoa consumption stimulated alterations in the redox-sensitive signaling pathways of human gene expression of immune response. Cocoa safeguarded the nerves from injury and inflammation. Skin was as well defended from the oxidative damage due to UV radiation in topical preparations, and had showed beneficial effects on the satiety, cognitive function, and mood.<sup>37</sup> Among the various powders that were analyzed, cocoa powder had the higher sources of ORAC and TF. Similarly, dark chocolate was a significantly more concentrated source of ORAC and TF than the fruit juices.<sup>38</sup>

### CONCLUSION

The beneficial effects of cocoa flavonoids on blood pressure and peripheral and central blood flow promoted improvement in cognitive performance. DC enhanced the cognitive function and cholinergic activity in hippocampal region of aged rats and also corrected their metabolic disturbances. Enhanced nitric oxide bioavailability with better mitochondrial function, promoted rewarding effect on the blood pressure, lipids, and inflammation. Inconsistencies were noted in the reporting of data with limited information on the beneficial effects of cocoa and chocolate on weight control and glycemic control, in spite of the potential benefits reported on cardiovascular risk factors of endothelial function and lipids.

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