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Could we make a Mars-sized Mars bar?

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Abstract
Making a Mars-sized Mars bar would be a truly astronomical feat. Due to its sheer size, materials from outer space would need to be used. This paper explores how and where the materials/ingredients for producing such a bar could be acquired and whether all necessary materials could be acquired/synthesised.

Keywords: *Chemistry; Astrochemistry; Food science; Mars; Mars bars*

Introduction
The planet Mars is the fourth-closest planet to the Sun, coming just after Earth. On the other hand, Mars, the chocolate bar, is a sweet confection. While the planet Mars is approximately 8 times larger than the moon, a Mars bar is small enough to fit in the palm of my hand [1, 2]. The number of Mars bars required to make a Mars-sized Mars bar is 6.6579×10^{24}. As a Mars bar weighs 51 grams to produce a Mars-sized Mars bar, we would need 3.3955×10^{22} kg of material. If future humans wished to harvest all this material from the Earth, it would constitute using the entirety of the crust [3]. As a result, off-Earth materials would be required. The feasibility of collecting material from these distant locations on such a large scale will not be discussed herein.

Required ingredients
Although the recipe used in the production of Mars bars is secret, by looking at the ingredient list, we can determine which compounds are required to produce a one (see table 1). To simplify this ingredient list some ingredients will be consolidated into a single ingredient.

As glucose is a precursor to lactose the sugars will be consolidated as Glucose. As the fats present are mostly made up of triglycerides we will consolidate the fats category as triglycerides. All proteins consist of amino acids and methods have been developed to chemically form amino acid chains [4]. As a result, the protein category will be consolidated as amino acids. Cocoa mass is just cocoa powder and cocoa butter (fat) so cocoa mass and fat-reduced cocoa can be consolidated as cocoa powder. As a result, the new required ingredient list is: *Glucose*, *fatty acids*, *amino acids*, *cocoa powder*, *natural vanilla flavouring* and *salt* (NaCl).

Sugars	Fats	Proteins	Flavourings
Sugar	Coca butter	Whey	Coca mass
Glucose syrup	Sunflower oil	Whey protein	Fat reduced coca
Lactose	Milk fat	Milk protein	Vanilla flavouring
Slimmed milk powder	Palm fat	Egg white powder	Salt (NaCl)
Barley malt extract	Soya lecithin	Skimmed milk powder	

Table 1 – Mars bar ingredients sorted into overarching biochemical groups [5].

Making Mars bar ingredients from space materials
If future humans wanted to find an abundant source of materials to carry out their astronomical chocolate-making plans, the first place they would look would be interstellar clouds. These clouds contain many different elements and compounds in abundance and research suggests they may even contain some of the required organic materials already [6].

Making the 3 main ingredients

Glucose, *fatty acid*s and *amino acids* are the most important 3 ingredients making up the bulk of the product having the ability to make these is essential. In dense interstellar clouds CO_2 gas and H_2O are present [7, 8] and studies have shown that non-biological production of glucose from CO_2 and H_2O is possible by using a closed loop production system based on glycerol [9].

Once glucose can be produced on a large-scale, fatty acids can be synthesised using non-biological methods. This is done by carrying out in succession hydrogenation, electrochemical reduction, Zeigler growth displacement and esterification [9].

Amino acids can be unnaturally synthesised via a series of substitutions, alkylations and aminations [10]. In both processes the addition of nitrogen and sulphur, 2 of the highest abundance elements, is required to make the amino acids. They are both highly abundant in interstellar and molecular clouds [11, 12]. While all the amino acids may be produced synthetically when doing so a racemic mixture of two enantiomers will be produced. In many cases this is not a problem as both produce the same smell and taste however in 7 amino acids the *d*-form produces a sweet taste that is absent in the *l*-form [13].

Making the additional flavourings

Although vanilla is not the main flavouring in a Mars bar combining other flavours with vanilla flavouring provide the unique flavour profile. Natural vanilla has extremely high production costs. As a result, the main flavour compound in vanilla, vanillin, is often synthesised chemically and used in its place [14]. Vanillin is mostly chemically synthesised from the precursors guaiacol or lignin and acquiring these precursors would be impossible in space due to their complex biochemical structures. An alternate method of turning glucose into vanillin is also present in literature however it is biosynthetic [15]. On such a large-scale, biosynthetic methods may not be possible however it is also possible that if research were carried out on conversion of synthetic glucose to vanillin a methodology could be produced.

Cocoa powder is essential to providing the chocolate flavour to a Mars bar. Studies have shown that about 600 chemical compounds contribute to producing the chocolate flavour of cocoa powder [16]. Exploring the possible replication of all these molecules will not be possible. I will consolidate molecules into functional groups and simply discuss whether molecules of those functional groups could be produced. Alkanes have been detected in interstellar space and I will use these as the start point for converting to the other required molecules [17].

Functional group	Precursor	Methodology/pathway
Alcohols	alkanes	Free radical substitution then nucleophilic substitution
Esters	Alcohols and Carboxylic acids	Esterification
Aldehydes	Primary Alcohols	Partial oxidation
Ketones	Secondary Alcohols	Oxidation
Carboxylic acids	Aldehydes	Oxidation
Pyrazines	Amino acids	Condensation and aromatization (oxidation)

Table 2 – Required precursors and chemical transformations for production of cocoa flavour compounds [18, 19]. Colours highlight precursors that can be acquired by using another pathway.

Salt, made up of sodium and chlorine, is an ingredient that enhances the bars overall taste. Both sodium and chlorine are less abundant in the universe than other components required so far [20] however ejecta of evolved stars is known to contain NaCl. Data from the ALMA telescope found its presence in the Protostellar disk of Orion Source I, suggesting Protostellar disks may also be a source [21]. Alternatively, the elemental constituent's sodium and chlorine could be collected from interstellar medium where they are present [22].

Conclusion

As shown in this paper, a civilization with the ability to acquire and chemically process astronomical amounts of material could produce a Mars sized Mars bar. This Mars bar would be structurally identical to the one on earth due to the replication of its structural elements. Although most of the flavour compounds were replicated some L-amino acids could not be replicated identically and vanillin may not be possible to replicate. As a result, the overall flavour would not be identical to the Mars bar on Earth

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