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Research Article

Impact of Various Carbohydrate Sources on Functional Attributes, Colony Population, Feed Intake, and Quality of Honey Produced by the Honeybee

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Abstract

The effect of various carbohydrate sources on bee function was investigated in this study. To conduct the experiment, 12 treatments in 6 replications in a completely randomized design carried out on *(Apis mellifera meda)*. The treatments are consisted of control treatment (honey, white sugar, brown sugar) and sweet dough treatments containing corn, potato, wheat starch and corn liquid fructose with ratios of 15 and 30%.population size, feeding rate and egg, larvae and pupae amount as well as honey production and honey analysis were investigated. The results of supplying the colonies with diverse starch targeted groups show that there is a significant difference between the highest and the lowest tested treatments ($P<0.05$). In conclusion starch content at 15% increased the performance of the honey bee in comparison to the 30% level. Thus, along with the starch sources it is recommended to use a small amount of 1:1 sugar syrup one day in between due to performance improvement, especially in the seasons when the flow of nectar is low. Sweet dough containing 15 and 30% corn liquid fructose improves honeybee efficiency. The purpose of this study is to select the appropriate alternative for white sugar in terms of economic, ease of supply and nutritional health for honey bee.

Keywords: *Bee, Carbohydrate sources, Attributes, Starch, Sweet dough*

Çeşitli Karbonhidrat Kaynaklarının Balarılarında Fonksiyonel Nitelik, Koloni Popülasyonu, Yem Tüketimi İle Üretilen Bal Üzerine Etkisi

Öz

Bu çalışmada çeşitli karbonhidrat kaynaklarının arı fonksiyonları üzerine etkisi araştırıldı. Araştırmayı yürütmek amacıyla tamamıyla rastgele dizaynda, 6 tekrar olmak üzere 12 deneysel uygulama *Apis mellifera meda* üzerinde gerçekleştirildi. Deneysel uygulamalar; kontrol uygulaması (bal, beyaz şeker veya kahverengi şeker) ile %15 ve %30 olmak üzere mısır, patates, buğday nişastası veya mısır sıvı fruktoz içeren tatlı hamurdan oluşmaktaydı. Popülasyon büyüklüğü, besleme oranı, yumurta, larva ve pupa miktarları, bal üretimi ve bal analizi araştırıldı. Farklı nişasta ile hedeflenen kolonilerde en yüksek ve en düşük uygulamalar arasında anlamlı farkların oluştuğu belirlendi ($P<0.05$). Sonuç olarak %30 ile karşılaştırıldığında %15 nişasta içeriği bal arısı performansını artırdı. Bu nedenle nişasta kaynakları ile birlikte aralarında bir gün olacak şekilde düşük miktar 1:1 şeker şurubu verilmesi özellikle nektar akışının düşük olduğu sezonlarda performansı geliştirebilir. %15 ve %30 mısır sıvı fruktoz içeren tatlı hamur balarısı etkinliğini iyileştirir. Bu çalışmanın amacı ekonomik, sağlama kolaylığı ve gıda sağlığı bakımından bal arılarında kullanılabilecek beyaz şekere bir alternatif belirlemektir.

Anahtar sözcükler: *Arı, Karbonhidrat kaynakları, Nitelik, Nişasta, Tatlı hamur*

INTRODUCTION

Researchers, scientists and severely beekeepers have a significant consideration of nutrition of honeybees to solve the upcoming challenges that affect their ability to stay healthy and improve the efficiency of production [1-4]. This condition gets intense in commercial bee operations that include a diverse management style regarding the colonies movement, quality and amounts of food. An intelligent decision on how to keep a honeybee is possible only when the fundamental demands for feeding bees correctly and in perfect detail has been investigated. In these insects,

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nutrition should be considered in a completely two independent manners, since the larval period is usually different from the adult insects. However, the process of feed intake of larva and adult bee are relatively close since a matured insect should actively and gradually feed larvae [5]. Nutrition involves all the operations by which an organism converts various nutrients, minerals, water, vitamins and other substances into body parts or acquired energy for various vital processes [5].

Barker and Lehner [6] reported that 4 mg of sugars is essential for an adult honeybee worker to survive, while Rortais et al.[7] calculated one worker larva needs 59.4 mg of carbohydrates.

Pollen, produced by flowers, is the major source of protein for honeybees [8], though it does not provide energy for the bee. Pollen grain supplies all the requirements of the colonies in terms of protein that plays a vital role in the growth of the body and is essential for the restoration of tissues and other body functions. The bulk of the contents of the honey is made up of glucose, fructose and sucrose, while the additional sugars content found in nectar, have less nutritive value. Considering the incapability of honeybees to break the additional content down, the utilized percentage has toxic effect during the ingestion [9]. In an emergency sugar and carbohydrates sources feeding can be used as a supplementary material or substitutes when the colony is running short of stored honey, especially in winters. For this purpose, dense phase of material is most probably suitable for feeding to bees. Attention to the protein components of the diet has to be taken into account to increase the population numbers [10].

To store the carbohydrates as honey disaccharides, decompose into monosaccharides to prepare an appropriate form of material for cell usage. Simultaneous to this transformation, honeybee synthesizes micro-organisms and diminish the volume of water. As much the produced material gets dense, the percentage of fermentation reduced. It helps to produce a stable honey with normal content [11] Fraudulent and adulterated honey production is a problem all over the world [12]. Above all, we do not know how to distinguish adulterated honeys taken from the colonies that were [12].

Starch is the main form of storage of carbohydrates in the tubers and endosperm of the plant seeds. It is a cluster of linear polymers that in which some of the alpha chain are linked with glucose units and is stored in the molecule as energy. Starch consists of two types of carbohydrate polymers called amylose and amylopectin Biochemically [13]. Amylose is a polymeric carbohydrate consisting of a large number of glucose units joined by glycoside bonds. Amylopectin is a relatively larger molecule in comparison with amylose, which is associated with heavy branches of 95% alpha 1-4 and 5% alpha 1-6. Due to the difficulty of complete separation of natural amylose from amylopectin existing in starch sources a pure component is not available in the market, although individually, phosphorylase-catalyzed enzymatic polymerization is the appropriate method [14].

Most starch amylose has a very small amount of lipids that, along with amylose, form free lipid and fatty complexes. In between all types of starch groups, wheat has a higher level of lipid and glycolipid [15]. The composition of lipid and amylose affects starch granules, both in terms of structure [16] and performance. Starch molecules arrange themselves in the plant in semi-crystalline granules. Each plant species has a unique starch granular size. For example, corn granular forms a multidimensional shape, wheat and potato starch creates convex and ovoid shape, respectively. Potato starch with 110≥ micrometer is positioned prior than wheat 30≥ and corn 25≥ in comparing the granular diameter of the starch sources [17].

The aim of this study was to investigate the sources and levels of carbohydrates in feeding honey bee and replacing these sources with white sugar to enhance performance, increase the quality of honey as well as affordable prices, ease of supply and usability for honeybees.

MATERIAL and METHODS

The experiment was carried out in 12 treatments in 6 replicates in a completely randomized design on *Apis mellifera meda* at the Agricultural Research Center of Isfahan for a period of 6 months. (March to September 2017). In this study, the tendency of feeding honeybee from sweet dough treatments was investigated. Controlling treatments of honey, white sugar, brown sugar accompanied by sweet dough with diverse percentages have been exerted as sweet dough containing 25% honey and 75% white sugar, sweet dough containing 15% potato starch, sweet dough containing 30% potato starch, sweet dough containing 15% wheat starch, sweet dough containing 30% wheat starch, sweet dough containing 15% corn starch, sweet dough containing 30% corn starch, sweet dough containing 15% corn liquid fructose and sweet dough containing 30% corn fluid fructose *(Table 1)*. The measurable attributes of feed intake, colony population, amount of egg, larva and pupae, honey production and honey analysis with respect to the diet were evaluated by the controlling treatments.

To conduct the study, 72 colonies were selected and based on the identification of each hive a balance was established. Each hive includes 5 frame; 2 of eggs, larvae and pupae (brood), 2 honey frames and 1 empty comb.

Moreover, it was attempt to provide a similar condition with respect to the flower pollen storage. Before the experiment, homogenization was performed to minimize differences in colony count in terms of population, infant and honey stock. Thus, homogenization began with the creation of a balance between strong colonies

Table 1. *The amount of nutrients in the starch used in this study*

Nutrients	Corn Starch (%)	Wheat Starch (%)	Potato Starch (%)
Fat	0.8	1.2	0.1
Protein	0.5	0.2	0.1
Ash	0.1	0.2	0.3
P	0.08	0.05	0.09

from the point of population and larva to weak colonies and continued by adding the honeycomb to honey-lacked colonies to harmonize the conditions. Hives with sister queens were used to coordinate the apiary and finally, the colonies were randomly divided into treatments. During this 6-month period, records were taken every 21 d.

The amount of feed consumed by the bees was calculated from the weight of the sweet dough given to the hive when they were eaten during the test. The brood breeding and population growth was calculated by measuring the level of brood (eggs, larvae and pupae) by a brood chamber. Tabulated empty frame in square centimeter was placed on the surface of the brood and the number of brood chamber was counted. Therefore, the brood growth rate and development of the population were calculated in each colony per square centimeter. Since there is no possibility of extracting all the honey contained in a hive, a number of clean frame, which were previously collected from hives, were weighed and the average weight of an empty frame was obtained. Afterwards, all honey frames contained in each hive were weighed and recorded. By subtracting the weight of empty hulls, the net weight of honey was obtained for each hive. At the end of the experiment, at least 150-100 gm of produced honey in the hive is sampled from each replicate of the controlling treatments. Samples transferred to the laboratory for qualitative control (physicochemical) experiments that to determine the amount of sucrose in honey, the Ferreling experiment was used by the Sucramat apparatus and the method of Polarized light was used to determine the ratio of fructose to glucose.

Statistical Analysis

Derived data were recorded by excel software and then analyzed for variance analysis using SAS (Statistical Analysis System) software which is developed by SAS [18] Institute for advanced analytics applying GLM procedure. Applying Duncan's multiple range tests, the average was compared at a probability level of 5%. All of parameters were examined as follows:

$$Yij = \mu + Ti + eij$$

Where Yij is individual observation, μ is the overall mean, Ti is the effect of treatment, and eij shows the random error.

RESULTS

The results showed that in the control treatments (honey, white sugar, brown sugar), the highest amount was related to honey treatment and the lowest amount of feed intake was related to brown sugar treatments, which showed a significant difference ($P<0.05$) the amount of feed consumed by honey bees was lower in sweet dough compared to the control group ($P<0.05$) *(Table 2)*.

The highest amount of feed in the treatments containing sweet dough was related to sweet dough containing 15% corn liquid fructose. Among starch containing treatments, the highest consumption was found in sweet dough containing 15% corn starch and the lowest amount was for sweet dough it contains 30% of wheat starch, that these two treatments showed a significant difference ($P<0.05$) Also, among the control treatments the highest population *(Table 3)* was for brown sugar treatment and the lowest amount for honey treatment, which showed significant difference ($P<0.05$). Among the treatments, the highest amount of population was found to contain 30% corn liquid fructose, which showed a significant difference with all treatments. In total, sweet dough treatments containing 15% starch were more than 30% starch in comparison with sweet dough treatments.

The amount of brood fertility (eggs, larvae and pupae) showed the highest levels of brown sugar and the lowest amount of white sugar in the control treatments *(Table 4)*, which showed a significant difference ($P<0.05$) and sweet dough treatment containing 30% potato starch had a higher numerical value than sweet dough treatment

Table 2. *The effect of different sources of carbohydrates on the average amount of feed intake*

Controlling Treatments		Average of Feeding Rate (g)
Honey		15750[a]
White sugar		15000[b]
Brown sugar		14250[c]
Sweet dough containing (%)	SD (25 honey & 75 white sugar)	3948.0[d]
	SD (15 potato starch)	1075.0[g]
	SD (30 potato starch)	645.0[h]
	SD (15 wheat starch)	2037.5[f]
	SD (30 wheat starch)	500.0[h]
	SD (15 corn starch)	2212.5[f]
	SD (30 corn starch)	636.0[h]
	SD (15 corn liquid fructose)	4137.5[d]
	SD (30 corn liquid fructose)	2750.0[e]
(P-value)		P<0.001
SEM		2385

SEM: *Standard error of means. Footnotes (a-h) show significant differences each column (P<0.05)*

Table 3. *Effect of various carbohydrate sources on the average population of the colony*

Controlling Treatments		Average of Hive Population (per/cm²)
Honey		5880^{cd}
White sugar		6022^{cd}
Brown sugar		6777^{ab}
Sweet dough containing (%)	SD (25 honey & 75 white sugar)	6110^{c}
	SD (15 potato starch)	5666^{cde}
	SD (30 potato starch)	5347^{ef}
	SD (15 wheat starch)	5570de
	SD (30 wheat starch)	5125^{fg}
	SD (15 corn starch)	5990^{cd}
	SD (30 corn starch)	4890^{g}
	SD (15 corn liquid fructose)	6675^{b}
	SD (30 corn liquid fructose)	7120^{a}
P-value		P<0.001
SEM		86

SEM: *Standard error of means. Footnotes (a-g) show significant differences each column (P<0.05)*

Table 4. *Effects of various carbohydrate sources on the average of brood*

Controlling Treatments		Average of Brood (per/cm²)
Honey		4320^{a}
White sugar		2612^{d}
Brown sugar		4410^{a}
Sweet dough containing (%)	SD (25 honey & 75 white sugar)	4232^{a}
	SD (15 potato starch)	3210^{c}
	SD (30 potato starch)	3407^{c}
	SD (15 wheat starch)	3210^{c}
	SD (30 wheat starch)	3763^{b}
	SD (15 corn starch)	3200^{c}
	SD (30 corn starch)	3130^{c}
	SD (15 corn liquid fructose)	3382^{c}
	SD (30 corn liquid fructose)	4176^{a}
P-value		P<0.001
SEM		242

SEM: standard error of means. Footnotes (a-d) show significant differences each column (P<0.05)

containing 15% potato starch, but no significant difference was observed between the two treatments (P>0.05). Sweet dough treatments contained 30% of wheat starch compared to sweet dough containing 15% wheat starch was higher in number and there was a significant difference between two treatments (P<0.05).

The amount of honey production and its quality *(Table 5* and *Table 6)* show that the control treatments did not show any significant difference in terms of honey production

Table 5. *Effect of various carbohydrate sources on the average production of honey*

Controlling Treatments		Average of Honey Production (g)
Honey		3125^{a}
White sugar		3175^{a}
Brown sugar		3075^{a}
Sweet dough containing (%)	SD (25 honey & 75 white sugar)	1825^{b}
	SD (15 potato starch)	1450^{bc}
	SD (30 potato starch)	967^{cd}
	SD (15 wheat starch)	1335^{bcd}
	SD (30 wheat starch)	1140^{cd}
	SD (15 corn starch)	1500^{bc}
	SD (30 corn starch)	775^{d}
	SD (15 corn liquid fructose)	1600^{bc}
	SD (30 corn liquidfructose)	2750^{a}
P-value		P<0.001
SEM		380

SEM: *Standard error of means. Footnotes (a-d) show significant differences each column (P<0.05)*

(P>0.05) but the highest amount was related to white sugar treatment and sweet dough containing 30% corn liquid fructose had no significant difference with control treatments, but there was a significant difference with other sweet dough treatments (P<0.05).

The highest amount of Hydroxyl methyl furfuran (HMF) is related to sweet dough containing 30% corn liquid fructose and the lowest amount is related to brown sugar treatment, which showed a significant difference and among the control treatments the highest amount of HMF was in white sugar and the lowest in brown sugar which showed a significant difference (P<0.05). The highest amount of sucrose was found in 30% corn starch containing sweet dough and the lowest amount of honey treatment showed a significant difference (P<0.05). The ratio of fructose to glucose in sweet dough treatments 30% corn starch and 15% corn fluid fructose and 30% corn fluid fructose did not show any significant difference. Also, there was no significant difference between the control group. Regarding the presence of artificial sugar, all treatments were negative and the starch content in honey was observed only in treatments containing 15% wheat starch and 15% corn starch.

DISCUSSION

The results showed that the highest amount of feed intake is related to honey treatment and the lowest amount is for sweet dough containing 30% wheat starch. Statistical analysis showed that there is a significant difference (P<0.05) between the highest and the lowest amount of starch sources used as nutrition *(Table 2)*. Conversely, Rate

Table 6. *Analysis of honey produced by hives fed with various sources of carbohydrates*

Controlling Treatments		HMF	Starch	Fructose/ Glucose (%)	Synthetic Sugar	Sucrose (%)
Limit of allowance		< 40 (mL/kg)	Negative	> 9	Negative	< 5
Honey		3.16^{de}	Negative	1.4^{b}	Negative	2.93^{i}
White sugar		3.8^{c}	Negative	1.4^{b}	Negative	15^{a}
Brown sugar		3.1^{e}	Negative	1.39^{b}	Negative	12^{b}
Sweet dough containing (%)	SD (25 honey & 75 white sugar)	5^{b}	Negative	1.14^{c}	Negative	6.14^{h}
	SD (15 potato starch)	5.2^{b}	Negative	1.15^{c}	Negative	7.8^{f}
	SD (30 potato starch)	3.7^{cd}	Negative	0.94^{c}	Negative	9.06^{d}
	SD (15 wheat starch)	4.1^{c}	Positive	1.14^{c}	Negative	7.83^{f}
	SD (30 wheat starch)	3.9^{c}	Negative	1.15^{c}	Negative	8^{ef}
	SD (15 corn starch)	5.2^{b}	Positive	1.7^{a}	Negative	9^{d}
	SD (30 corn starch)	3.5^{cde}	Negative	1.6^{ab}	Negative	9.38^{c}
	SD (15 corn liquid fructose)	3.8^{c}	Negative	1.5^{ab}	Negative	8.06^{e}
	SD (30 corn liquid fructose)	13.5^{a}	Negative	1.5^{ab}	Negative	7.5^{g}
(P-value)		P<0.001		P<0.001		P<0.001
SEM		1.71		0.10		1.13

SEM: *standard error of means. Footnotes (a-i) show significant differences each column (P<0.05)*

of feeding 30% potato starch with 30% corn starch and 30% wheat starch treatment did not differ significantly (P>0.05). Amid the sweet dough containing starch, the highest feed intake of it was for 15% corn starch that did not show any significant difference with 15% wheat starch (P>0.05). However, there was a significant difference with sweet dough containing 15% potato starch that estimated to be due to starch diameter size. Respectively, Potato starch, wheat and corn are placed in the next position. As Cornell and Wallace [19] and later Kim and Huber [20] reported that digestion of various starches depend on the structure and the shape. Taking into consideration, the botanical origin plays an important role to form starch of various sources as oval, rounded and truncated with diverse range of diameter.

In comparison with other treatments, consumption of white sugar was higher subsequently than honey treatment, which is corresponded with the results of Ruiz-Matute et al.[21] and Weis [22] indicating the amount of white sugar was higher than the rest of the treatments. Of the total sugars consumed by bees, sucrose is most important in terms of acceptance and nutritional value demonstrating by Vogel et al.[23]; furthermore, it is in line with the consequences of this study. In control treatments, the highest feed intake was related to honey, white sugar and brown sugar, respectively which showed a significant difference (P<0.05). Also, sweet dough containing 15% fructose after control group had the highest consumption. In addition, it is consistent with outcomes of Barker and Lehner [6], the consumption of corn syrup containing fructose was utilized further by bees. This rate is due to the similarity of sugars inside the corn liquid fructose with honey.

In this research, the highest population size was for sweet dough contains 30% corn liquid fructose while the lowest amount obtained for the treatment containing 30% corn starch *(Table 3)*. The evaluation of the two treatments showed a significant difference. LeBlanc et al.[24] revealed the result of their study as corn fructose has no toxic effect on the bee and increases the population that is one of the substantial resultants of this research.

Long-term accumulation at high temperature and abundance of HMF shift the condition in which the corn fluid fructose can initiate toxicity and reduce the life span of the bee [21]. The highest population of starchy treatments is related to the sweet dough comprising 15% corn starch. To specify the correlation of this trail with sweet dough treatments contain 30% potato, 30% wheat and 30% corn starch (P<0.05). This is because corn starch possesses more proteins than other starches [25]. Haydak [26] reported that protein is undoubtedly a major contributor to the feeding of larvae and adult bees and expand the lifetime of the bees.

Considering the observations the population declined through supplying the feed by sweet dough containing 30% starch rather than 15%. It addresses that reducing the population is directly related to the amount of food consumed. Furthermore, Burenside and Vvansell [27] expressed objectivity of a direct link between the amount of sugar intake and the life of the bees while the relevance of low sugar reception with death was not yet determined. They presented that there is no clue for the conclusion of the exact reason of death concerning the toxicity due to the consumption of some sugars or low sugar reception.

The lowest colony population was found in sweet dough treatments containing 30% corn starch and 30% wheat starch due to high level of amylose [28]. Therefore, this factor decreases the digestibility and the same reduced the population size.

Among the control treatments, the highest amount of the population was for brown sugar, while the lowest amount was for honey and white sugar respectively ($P<0.05$).

Brouwers [29] in a study of the effect of glucose and fructose levels on bee honey diet on larval stages showed that glucose is the main source of glucose in the larval diet, as well as in all stages of the larvae of the bees The worker and the male are glucose, and fructose is a major source of growth in the next stages of larvae. Therefore, the presence of these sugars in honey and sugar can increase the population of bees' population that matches the results.

In this research, the maximum number of egg, larvae and pupae produced by feeding the colonies with treatment of the brown sugar. This is probably due to molasses in brown sugar containing proteins, energy and minerals, which can increase larvae and pupae. Also, all treatments containing sweet dough and control group with white sugar had a significant difference ($P<0.05$).This study was inconsistent with the results of Sammataro and Weiss et al.[30], which states that the use of sucrose syrup rather than corn liquid fructose treatment increases egg and larvae.

Also, no significant difference was observed between controlling treatments of (honey, brown sugar) and sweet dough containing 30% corn fluid fructose *(Table 4)* but with other treatments there was a significant difference between sweet dough containing starches.

According to observations, utility of sweet dough treatments containing 15 and 30% starch showed better spawning than white sugar. Correlation of the two treatments was over 0.05 resulting to a significant difference. Likewise, the same relevance authenticated between sweet dough containing 30 and 15% liquid fructose and White sugar. This research was consistent with the results of Sammataro and Weiss [30] that the use of sucrose syrup does not increase the egg and larvae in comparison with corn-fructose treatment. Similarly, the results are consistent with Schneider and Blewis [31], which showed that starch, increases the population and health of the colony. Adaptation of the consequences of this study with Woodring et al.[32] was zero, as they reported that sucrose increases the spawning rate. Probably the reason for the decrease in egg, larvae and pupae in white sugar treatment compared to the rest of the treatments is because of some protein and minerals component of starch treatments [25] that nursing bees need them, especially protein materials, to more care the brood and handle the condition of the egg, larvae and pupae.

Christy et al.[33] found in the comprehensive study of more than 20 types of sugar in honey, many of which are not found in nectar, and are produced by the honey enzymes and acids in the process of getting honey and in the reservoir. Simple sugars, dextrose volvulus, are the dominant sugar content of honey and have the property of absorbing moisture and energy production for honey-bees, and since honey is rich in other nutrients and can provide all the needs of the brood and increase the emerged rate and increasing the generation that is being matched by research.

The results showed that the highest amount of honey production was related to white sugar treatment and the lowest amount was for sweet dough containing 30% corn starch. Investigating the relationship between these two treatments demonstrated a significant difference at 5% level. Woodring et al.[32] reported that consumption of sucrose increased honey. Also there was no significant difference between white sugar, honey and brown sugar as the control group with sweet dough treatments containing 30% liquid fructose. Likewise, sweet dough containing 15% corn liquid fructose, corn starch, potato starch and wheat starch did not show any significant difference ($P>0.05$).

White sugar treatments had the highest amount of honey production than all treatments, and no significant difference was observed between sweet dough containing 30% corn liquid fructose with control group ($P>0.05$). In total sweet dough products containing starch were 15% higher than the 30% level.

Following supplementary studies, a direct relation between the rate of honey production and population was obtained [26]. Factors that increase population concurrent raise the number of nectars in the hives. No significant differences were observed between the control treatments (white sugar, honey, brown sugar), while the control treatments with the remaining showed a significant difference at 5% level. In the observations, sweet dough treatments containing 15% starch had more population, compared to sweet dough containing 30% starch that collected more honey *(Table 5)*.

In the analysis of honey *(Table 6)*, the highest amount of sucrose was related to white sugar with a rate of 15% and the lowest was for honey treatment, which showed a significant difference. Also, the result of sweet dough containing 15% of potato starch was significantly different from sweet dough containing 30% of potato starch. However, sweet dough containing 15% of wheat starch and sweet dough containing 30% of wheat starch did not show any significant difference and the amount of sucrose in white sugar treatment is higher than sweet dough containing corn liquid fructose that is consistent with the studies that were reported by Guler et al.[34], the amount of sucrose in white sugar treatment was higher than in corn liquid fructose treatment and had a significant difference

(P<0.05). In the observations, the highest amount of HMF was observed in sweet dough containing 30% corn fluid fructose and the lowest amount was for brown sugar. There was a significant difference between white sugar, honey and brown sugar as a control controlling treatments. HMF levels in sweet dough containing 15% corn liquid fructose and white sugar were the same which was consistent with studies by Guler et al.[34] that there was no significant difference between white sugar treatment and corn liquid fructose treatment (P>0.05). The highest amount of (HMF) observed in sweet dough contains 30% corn liquid fructose. Weiss et al.[22] and Ruiz-Matute et al.[21] reported that corn liquid fructose syrup would increase the amount of HMF in the production process if not maintained in proper condition.

The ratio of fructose to glucose in sweet dough containing 15% corn starch was highest and the lowest value was for sweet dough containing 30% of potato starch, which showed a significant difference. White sugar, brown sugar and honey did not differ significantly (P>0.05) but there was a significant difference between them and sweet dough (P<0.05). The ratio of fructose to glucose in sweet dough containing 30% potato starch was lower than all treatments, which probably made it easier for bees to alter potato starch to become glucose. Gomand et al.[28] reported that the highest level of amylose is related to wheat starch and the least associated with potato starch, and the degree of amylose and amylopectin polymerization of potato starch is higher than the rest of the starch sources. Fructose-Glucose ratio did not show significant difference in sweet dough composition containing corn liquid fructose with white sugar which is inconsistent with the results of Guler et al.[34].

No synthetic sugar was observed in any of the treatments, and starch content of honey in two treatments of sweet dough containing 15% wheat starch and sweet dough containing 15% corn starch were positive. This is probably due to the higher consumption of these treatments compared to sweet dough treatments containing 30% starch. Gomand et al.[35] reported that amylose content of wheat and corn starch was more than potatoes, as well as the number of amylose in corn and wheat starch that is more than potato. The solubility of potato starch is most. The total of factors in terms of the status of amylose and amylopectin, as mentioned above, are effective in digestibility of bees. Due to the high consumption of sweet dough containing 15% corn starch and sweet dough containing 15% wheat starch along with the low digestibility of bees, because of the high level of amylose, starch cannot break down in digestion system of the honeybee and thus enters into honey.

In conclusion, the nutritional effects of a food must be tested in different ways. Only accepting and consuming that substance by honey bees cannot be a precise criterion for judging its quality. In addition to its intake, other factors such as the effect of that substance on colony population, brood population and production honey should be investigated. Starch sources can be used in feeding bees, but the research showed that due to the different starch structure, the effect of each starch source on the performance of honey bees is different, and the level of 15% of starch in the total yield of honey bees compared to level increased by 30%. In this study, corn liquid fructose, considering the economic cost of white sugar, as well as increased yield, could be a good alternative to sugar and it is also recommended that starchy sweet potatoes can be used in the treatment of 15% starch content because with increasing starch content, we are faced with a decrease in bee function such as population decline and honey production.

In this research, other studies, such as heating, and the amount and duration of heating of various starch sources, can be studied, and their impact on consumption and performance increase.

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