Evaluating the Nutritive Value of the Pollen Substitutes Used Commercially for Feeding Honey Bee, *Apis mellifera* L., Colonies in Tripoli, Libya

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Abstract

The present field study was carried out from August 12 to Nove006Dzber 4 , 2001 to evaluate the nutritive value of the pollen substitutes used commercially for feeding honey bee , *Apis mellifera* L. colonies in Tripoli area , Libya . These substiutes included Nectapoll $^{(R)}$ paste produced by Hamman Company in Germany and the Libyan Paste produced by Tripoli Society of Beekeepers. The chemical analysis showed that the protein concentrations were about 2% and 1% in Nectapoll$^{(R)}$ paste and Libyan paste, respectively. The rates of consumption varied from 60.1-90.0 and 83.7–152.7g / week / colony of the two pastes, respectively. Although the consumption rate of Libyan paste was significantly higher than that of Nectapoll$^{(R)}$ paste (P<0.05), both of the pastes had no beneficial effects regarding brood rearing, adult population, and colony weight when compared with unfed (control) treatment. We believe that the failure of these foodstuffs might have been caused by more than one factor, especially low concentration of protein, lack of certain nutrients and low rate of consumption (unpalatability)

الخلاصة

اجريت هذه الدراسة الحقليه خلال الفترة الممتده من 8/12 الى 2001/11/4 من اجل اختبار القيمة التغذويه لبدائل حبوب اللقاح المستخدمه على نطاق تجاري واسع لتغذية طوائف نحل العسل، *Apis mellifera* L. , في منطقة طرابلس ، ليبيا . بدائل حبوب اللقاح المشموله بالدراسه هي : عجينة Nectapoll$^{(R)}$ من انتاج شركة Hamman الالمانيه و عجينه محلية الصنع تسمى "عجينة الجمعيه" من انتاج جمعية النحالين في طرابلس . اثبت التحليل الكيميائي بأن تركيز البروتين كان بحدود 1% و 2% في العجينتين المذكورتين على التوالي . أما معدل استهلاك النحل للعجينتين المذكورتين على التوالي فإنه تراوح بين 60.1–90% و 83.7 – 152.7 غم / طائفة / اسبوع وبفارق معنوي مؤكد (تحت مستوى معنوية 0.05) لصالح عجينة الجمعية . لم يكن لأي من العجينتين أي تأثير معنوي إيجابي فيما يتعلق بالأوجه التالية من نشاط النحل : تربية الحضنة ، مجموع النحل الكامل ووزن الطائفة ، إذا ما قورنت بالأنشطة الموجودة في الطوائف غير المغذاة (معاملة المقارنة) . وأخيراً ، فإننا نعتقد بأن فشل العجينتين ربما كان عائداً لأكثر من عامل واحد وخاصة تدني تركيز البروتين ، غياب عناصر تغذوية مهمه ، وتدني صفة الاستساغة.

Introduction

When honey bee, *Apis mellifera* L., colonies face a lack of natural pollen in their hives and in the field, their growth and development can highly be limited (Free,1967; Free& Williams, 1971). Under such a circumstance, beekeeper should feed the colonies either pollen supplement or pollen substitute (Purdie and Doull , 1964; Doull, 1980). There have been many studies carried out to test numerous kinds of plant and animal products in attempts to find a substitute to replace pollens in their natural diet but none of these products has been found that is a complete replacement for natural pollen. However, some protein foodstuffs could improve nutrition and ensure continued colony development (Standifer *et al.*, 1978). The most commercially available products in the USA are: soybean flour, torula yeast, wheast (a dairy yeast), and brewer's yeast. Many other non-floral protein sources have been tested and / or used in different countries including dried skimmed milk, bakers yeast, powdered casein, lactalbumin, fish meal, flours of wheat, maize, sorghum, sunflower, peanut, . . . etc. (Standifer, *et al.*, 1978; Gojmerac, 1980; Hayes, 1984; Morse, 1990; Herbert, 1992).

Although many scientists and beekeepers have advocated the efficiency of various supplementary diets, we still find other scientists who are suspicious in many cases of this efficiency. For example, Barker (1977) mentioned that substitutes for pollen such as soybean flours have been fed to bees with inconsistent results; the differences in flours are recognized but the speciation for substitutes are superficial. Kulincevic *et al.* (1982) found that feeding an inferior pollen substitute was a cause of commercial beekeeping losses in Florida. Cook and Wilkinson (1986) believes that pollen substitute diets produce inconsistent results and not always stimulate egg-laying. Many factors have been found to be reasons standing behind the failure of many artificial foodstuffs used as pollen substitutes. These factors are: 1. unsuitable size of flour particle size (Herbert, 1992, Morse, 1990), 2. unsuitable concentration level of protein, i.e. either too high or too low (Lehner, 1983. ; Peng, *et al.*, 1984; Herbert, 1992), 3. deficiency of essential amino acids for honey bees and / or lack of certain fatty acids, vitamins, minerals, and enzymes (Herbert, 1992; Rogala, and Bozena, 2004 ; Manning *et al.*,. 2007), 4. presence of toxic substances to honey bees such as stachyose (Barker, 1977), 5. lack of palatability (Waller *et al.*, 1970). Many parameters have been used for judging the efficacy of pollen substitutes. Parameters of colony growth and development include egg laying and brood area, colony population size, honey production, . . . etc. Bees physiological parameters include size and development of hypopharyngeal glands, bee longevity, size of fat body, number of haemocytes, . . . etc.

There has been a promising beekeeping industry in Tripoli area , Libya . The honey bee , *Apis mellifera* L. , colonies , however , undergo a sharp decline in growth and development soon after the honey harvest season because of many factors including sever shortage of pollen and nectar in the flield , increase of ambient air temperature , and presence of the bee eater , *Merops* sp. The beekeepers try to overcome such a natural defect through supplying their colonies with pollen substitutes. There have been two main private sources for supplying the beekeepers with large quantities of these foodstuffs: the Tripoli society of Beekeepers and the German Hammann Company. These sources offer their products as pastes wrapped in waxed paper, but without mentioning any information about neither the paste contents nor their chemical analysis. Since there was no any neutral scientific evaluation for the efficacy of these products, especially the beekeepers have been paying large amounts of money for them, the senior author was officially asked to conduct this field study to evaluate their nutritive value for honey bee colonies.

Materials and Methods

The study was conducted in the apiary of the College of Agriculture, Al-Fateh University, Tripoli, Libya from August 12 to November 4, 2001. Eleven Italian honey bee, *Apis mellifera ligustica*, colonies headed by sister mated queens, almost equal in strength, and housed in one-story hives of Dadant type were used for the test. The hives were put under a shade made of plant materials to protect the colonies from direct sunlight.

Two types of products, supposed to be pollen substitutes, were subjected to the test. One of the pastes, called the Libyan paste, is manufactured by the Tripoli society of Beekeepers. The another paste, registered under the trade mark Nectapoll(R), is a product of Hammann company in Germany. Each of the paste treatments was randomly replicated in four colonies whereas three other colonies were left unfed to represent the control treatment. Each of the fed colonies was initially given 150g of the paste involved that was placed on the top bars in the brood nest area. Then, and when there was a small amount of the paste remaining it was removed and another fresh paste of the same weight was added.

To evaluate the effect of these products, the following criteria were used. Samples of the pastes were sent to two scientific neutral centers for chemical analysis: the Advanced Laboratory of Chemical Analysis, National Board of Scientific Research in Libya and the Department of Food Science, Faculty of Agriculture, University of Aleppo in Syria. The amount of the paste consumed by each colony was determined weekly by means of a sensitive scales. The area of worker sealed brood, colony weight, and size of adult population, in each colony were measured every two weeks. The area of brood was measured by means of a two-centimeter square mesh wire grid. Each hive with its all contents was weighed by means of a movable 100-kilogram scales. The size of adult population was determined by counting the combs covered completely with adult bees on both sides (Gary *et al.,*. 1978). Although the colonies were approximately equal in their strengths, they were not identical. For this reason we took pretreatment readings just before adding the pastes , so the statistical analysis of data is based on adjusted values by applying covariance analysis (Little and Hills, 1978).

Result and Discussion

1. Chemical Composition of Foodstuffs

Table (1) shows the chemical composition of both of Nectapoll$^{(R)}$ and Libyan pastes. The protein concentration in the Libyan paste was about 1% wheareas it was about 2% in Nectapoll$^{(R)}$ paste. It is well known that protein is the most important component of both natural pollen and pollen substitutes. The honey bees require protein primarily as a source of essential amino acids (Barbier, 1970). According to the scientific studies carried out on honey bee nutrition, the protein concentration levels of the present pastes are far from fulfilling bee requirements. Barbier (1970) found that the total protein of flowering plant pollens varies from 7 to 35% (avg. 24%). Some studies tested five level of protein ranging from 5 to 50% in certain pollen substitutes. The results of these studies showed that the optimal level was 23%; the highest level (50%) caused protein toxicity whearas the lowest level (5%) reduced egg-laying rate (Lehner, 1983; Herbert, 1992).

The chemical analysis also showed no lipids (fats) at all in both pastes. Lipid concentration in natural pollen varies from 1-15%, with average of 5% (Kulincevic *et al.,*. 1982). It seems that honey bee requires sterol, for all insects studied critically were found to require a dietary of this lipid (Todd and Bishop. 1940). Pollen substitutes; therefore, should contain certain concentration of lipids.. Manning *et al.,* (2007) found that the life spans of bees fed soybean flour were 26 days on low (0.6% lipid) fat, 19 days on defatted and 20 days on full-fat diets.

Table (1). The Chemical Composition of the pollen Substitutes *

Pollen Substitute / Component	Netapoll(R) paste	Libyan Paste
Moisture	6.31%	1.80%
Protein	1.712% 2.035% **	0.744% 1.097% **
Sucrose	7.45%	5.44%
Reduced Sugars	13.917%	74.011%
Fat	None	None
Ash	0.15%	0.18%
Potassium	9.24 ppm	10.24 ppm
Calcium	85.3 ppm	113.2 ppm
Phosphorous	0.0246 ppm	0.02415 ppm
Sodium	11.46 ppm	27.07 ppm
Zinc	3.15 ppm	3.40 ppm
Magnesium	1.24 ppm	1.09 ppm
Iron	7.36 ppm	11.17 ppm

* The analysis conducted by the Advanced Laboratory of Chemical Analysis, National Board of Scientific Research, Libya.

** The analysis conducted by the Department of Food Science, College of Agriculture, University of Aleppo, Syria.

2. Consumption Rates of Pastes

Mean consumption rates varied from 60.1-90.0 and from 83.7-152.7gm / colony / week of Nectapoll(R) and Libyan paste, respectively (Figure 1). The statistical analysis ($P<0.05$) shows that the rate of consumption of Nectapoll(R) is significantly lower than that of Libyan paste. The difference was steadily increasing week after another, especially after the third week. While the difference between the two means of consumption at the beginning was 23.6g colony / week, it reached 74.6g at the end of study; i.e. the bees consumed twice as much Libyan paste as Nectapoll(R) paste. We believe that the high concentration of sugars in Libyan paste (see Table 1), rather than its nutritive value, might be behind this result when compared with Nectapoll(R). It is known that addition of sucrose, honey, or 10% pollen to a supplement fed to bees improves palatability (Standifer *et al.*,. 1978; Herbert, 1992). Other studies demonstrated that the addition of some oils, such as anise oil, to the substitutes had increased the palatability and consumption rate (Waller *et al.*, 1970).

Rate of consumption is one of the parameters used for evaluating pollen supplements and substitutes (Standifer *et al.*,. 1978; Morse, 1990; Herbert, 1992). This rate; however, can be affected by many other factors including colony strength, colony flight activity, availability of natural pollen, distance between the colony and the field, . . . etc. For instance, Goodwin *et al.* (1994) found in a study conducted in New Zealand that a group of bee colonies consumed about 823gm / colony / week whereas another group, located in another site, consumed about 250g / colony / week of the same substitute because the two cites differed from each other regarding the availability of natural pollen in the field. In the present study the rates of consumption, even in the Libyan paste treatment, were low despite the severe shortage of natural pollen. This may indicate that the pastes were either poor in their nutritive value or unpalatable or both.

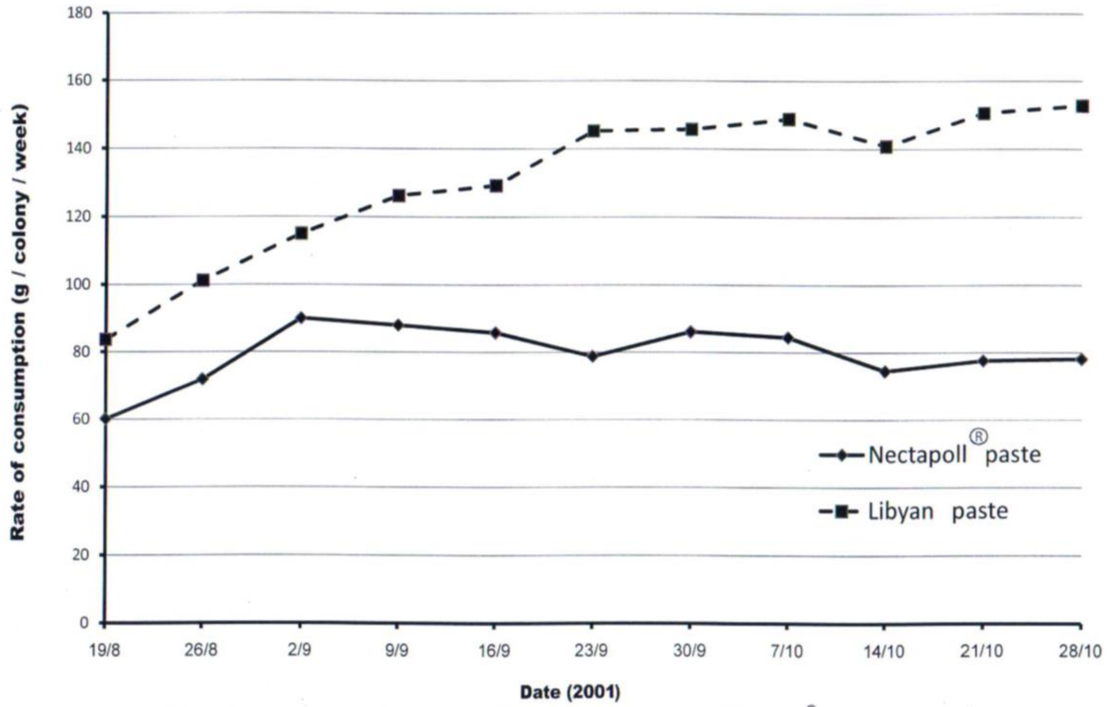
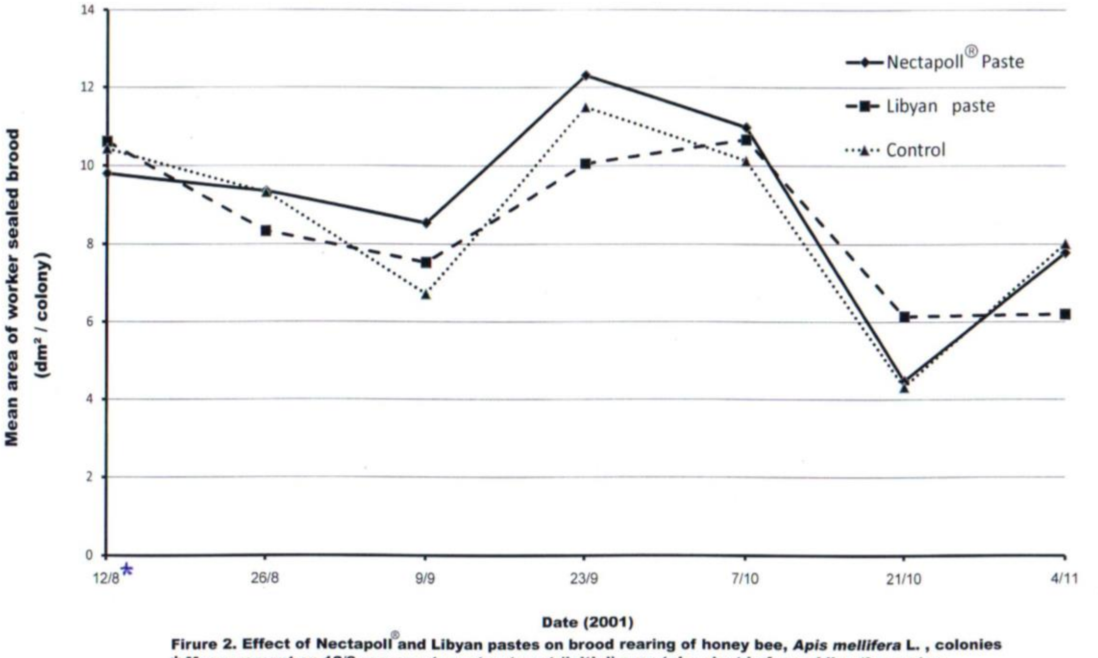


Figure 1. Rates of honey bee ,*Apis mellifera* L., consumption of Nectapoll® and Libyan Pastes

3. Brood Area

Figure (2) shows both of the pre-treatment and post-treatment means of worker sealed brood area of fed and unfed colonies. The statistical analysis of adjusted values ($P<0.05$) showed that both of the pastes had no significant beneficial effect on brood rearing. We believe that the period of present test (August 12 to November 4) was adequate to reveal the potentials of these pastes, if any, to increase the brood areas. Since the protein concentration level in the pastes (Table 1) and the consumption rates (Figure 1) were low, it would not be surprising not to find any improvement in brood rearing activity.

Many studies have pointed out that pollen substitutes containing the proper nutrients and palatability character were able to improve brood rearing in the colonies (Haydak, 1976; Loper and Berdel, 1980; Sabir, *et al.*, 2000 ; Saffari *et al.*, 2004; Madras *et al.*, 2005). Rogola and Szymas (2004) found that a pollen substitute enriched with synthetic amino acids had beneficially affected the physiological condition of bees expressed in terms of the high degree of development of the hypopharyngeal glands and of the fat body. We know that these glands secrete a major component of royal jelly required for larvae and queen nutrition. On the other hand, there have been also studies pointing out the failure of some substitutes in this domain (Barker, 1977 ; Kulincevic*et al.*, 1982; Cook and. Wilkinson. 1986).



Firure 2. Effect of Nectapoll® and Libyan pastes on brood rearing of honey bee, *Apis mellifera* L. , colonies
*** Measurement on 12/8 represents pretreatment (initial) area taken just before adding the pastes**

4. Adult Bee Population

Again, the statistical analysis of adjusted values ($P<0.05$) showed that there were no significant differences between the means of adult bee population sizes in fed and unfed (control) colonies.

It has been an axiom that the size of adult population in any colony at a given period is an expression of brood rearing activity during the preceding period (Bodenheimer and Ben-Nerya. 1937; Morse, 1990; Wyoke, 1992). This, of course, aggress with the results of the present study (see Figure 2). Peng *et al*. (1984) found that colonies fed protein supplement containing 21% protein from Torula yeast yielded high adult population compared with unfed (control) colonies. Other scientific studies demonstrated similar beneficial effect (Sabir *et al.,*. 2000; Saffari *et al.,*. 2004). In Figure 3 we notice that the adult populations of unfed colonies were larger than those of fed colonies in most weeks, although the differences were insignificant. We may speculate that the pastes might have decreased the life spans of adult bees (Manning *et al.,* 2007).

Note. As it has previously been mentioned, the bee colony population in Tripoli area face a sharp decline soon after honey extraction in summer. This explains why such small sizes of populations were found in both fed and unfed colonies. Such a decline in bee populations also happens annually during nearly the same period, especially in August and September, in central Iraq because of similar reasons (personal observation).

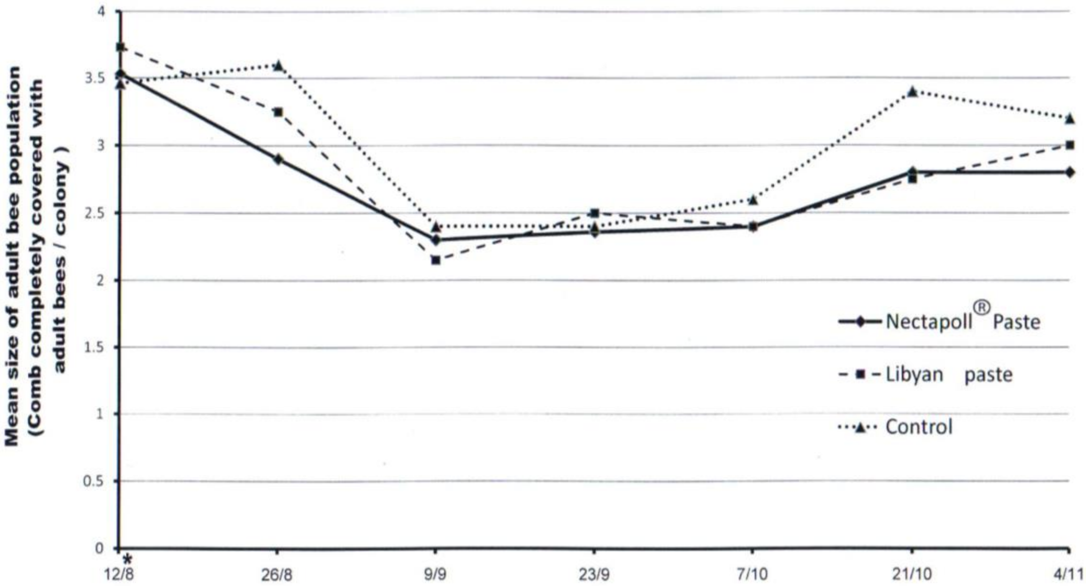


Figure 3. Effect of Nectapll® and Libyan pastes on adult population of honey bee , *Apis mellifera* L., colonies
*** Measurement on 12/8 represents pretreatment (initial) area taken just before adding the pastes**

5. Weight of Whole Colony

Figure (4) shows the successive changes in colony weights of fed and unfed treatments. The statistical analysis of adjusted values ($P<0.05$) showed insignificant differences between the means at all dates. It is worth mentioning that the successive weighing of the whole hive altogether with the occuping colony is usually practiced by both the scientific researchers and practical beekeepers in order to pursue the change of nectar collection rate (Gary *et al.*, 1978).

In Canada Saffari *et al.* (2004) tested the effect of two commercial substitutes, Feed bee$^{(R)}$ and Bee-Pro$^{(R)}$, against natural pollen. They found that the means of honey production were 71, 71, 33, and 39 kg / colony in Feed bee$^{(R)}$, natural pollen, Bee-Pro$^{(R)}$, and control (unfed) treatments, respectively. This result clearly points out that one of the substitutes was as superior as the natural pollen whereas the another substitute was too inferior to the extent that it was equivalent to the control (unfed) treatment. Of course, such a superior substitute could not have increased honey production without increasing first the brood area and adult population.

Finally, we may conclude from all the above mentioned results that both Libyan and Nectapoll$^{(R)}$ pastes failed to be considered as pollen substitutes. It is well known that the beekeeper feed their colonies pollen supplements or substitutes during summer and fall seasons to ensure that the colonies will be able first to pass the winter properly and second to produce more splits and honey in the next season.

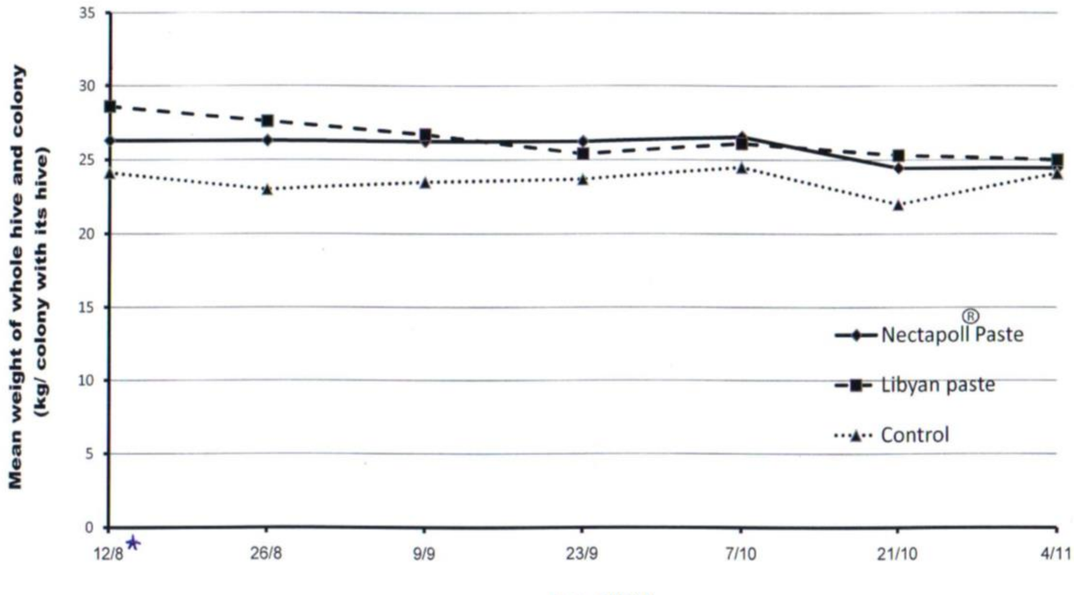


Figure 4. Effect of Nectapll® and Libyan pastes on colony weight of honey bee , *Apis mellifera* L.
*Measurement on 12/8 represents pretreatment (initial) size taken just before adding the pastes

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