**STable 1 The content of active ingredients from each bee products.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Bee products** |  | **Biomacromolecule** | **Secondary metabolite** | **Ref** |
| **Carbohydrates** | **Protein/peptides** | **Fats/ Fatty acids** | **Terpenes/carotenoids others** | **Polyphenols /flavonoids** |
| **Bee collection and brewing products** | BB(Morocco) | Total free sugars (18 ± 1 g/100 g) | (19.96 ± 0.08 g/100 g) | Polyunsaturatedfatty acids(64.7 ± 0.4%) |  |  | ([1](#_ENREF_1)) |
|  | BB(Lithuania) |  |  |  |  | 196.3–221.6 mg RUE/100 g ;78.8–156.7 mg RUE/100 g/ | ([2](#_ENREF_2)) |
|  | BB (Portugal) | 58–78% | 14.1–21.8% | 3.6–16.8% |  |  | ([3](#_ENREF_3)) |
|  | BB(not one kind) | (24–35%)Monosaccharides 93.96%Fructose (18.95%)Glucose (11.54 %) | 21.93 and 22.12 % | 7.79 % |  |  | ([4](#_ENREF_4)) |
|  | BCP/BB(Portuguese/Japan) | 24–60 %-24–35% g | 20% protein | 3% Lipids |  |  | ([5](#_ENREF_5))([6](#_ENREF_6)) |
|  | BCP/BB(Turkey) |  |  |  |  | 8.26 ± 0.29943.42 ± 0.779 mg GAE/g;1.81 ± 0.040–4.44 ± 0.125 mg QE/g; | ([7](#_ENREF_7)) |
|  | BCP(Lithuania) |  |  |  |  | 331.4–550.4 mg RUE/100 g ;108.2–468.5 mg RUE/100 g | ([2](#_ENREF_2)) |
|  | Honey(Germany &Urbana) | Fructose (38%) and glucose (31%) |  |  |  |  | ([8](#_ENREF_8)) |
|  | BCP(Białystok) | Carbohydrates (13–55%) are primarily fructose and glucose | Proteins and amino acids (10–40%) | Fats (1–20%) |  |  | ([9](#_ENREF_9))  |
|  | BCP(Brazilian) | 68.10% and 75.51% | 19.44% and 23.80% | 2.66–7.34% |  |  | ([10](#_ENREF_10))([11](#_ENREF_11)) ([12](#_ENREF_12)) ([13](#_ENREF_13)) |
|  | BCP (Colombian) | Fructose (19.5 ± 0.9)Glucose (13.6 ± 2.4)Sucrose (6.7 ± 2.0) | 23.8 ± 3.2 g | 6.90 ± 3.5 g |  |  | ([13](#_ENREF_13)) |
|  | Honey(Lithuania) |  |  |  |  | 2.95–10.18 mg RUE/10 g ;0.28–5.22 mg RUE/10 g | ([2](#_ENREF_2)) |
|  | BCP (Brazilian) | Glucose 8.77–19.12 %Fructose14.45–20.23 % | 17.58–21.91% | 6.14–9.2 % |  |  | ([10](#_ENREF_10)) |
|  | BCP(not mention) |  |  | 1–13 % |  |  | ([14](#_ENREF_14)) |
|  | BCP(not mention) | 18.50–84.25%reducing sugars 13–55%  | Proteins and essentialamino acids (5–60%) | (0.15–31.26)% USF and SF  |  | total phenolic content is (0.69–213.20 mg GAE/g) | ([15](#_ENREF_15))([16](#_ENREF_16)) |
|  | BCP(Scotland) | 13–55% | Protein and amino acids (10–40) % | Lipids (1–13) % |  |  | ([17](#_ENREF_17))([18](#_ENREF_18))([4](#_ENREF_4))([1](#_ENREF_1)) |
|  | Honey (not mention) | 95–97% | 0.041% |  |  |  | ([19](#_ENREF_19))([20](#_ENREF_20)) |
|  | Honey(not mention) | 82.4%31% glucose, 38.5% fructose, 12.9% other sugars | 0.5% |  |  |  | ([21](#_ENREF_21))([22](#_ENREF_22)) |
|  | Honey(not mention) | 82.40Glucose 35.75, Fructose 40.94, Sucrose 0.89,Maltose 1.44, Galactose 3.10 | 0.30 |  |  |  | ([23](#_ENREF_23)) |
|  | BCP (Brazil) |  | 10.6–33.9 % | 3.2–8.3 % |  | 5.6–29.7 mg GAE/g0.3–19.0 mg QE/g | ([24](#_ENREF_24)) |
|  | BCP (Serbia) | 64.42–81.84% | 14.81–27.25% | 1.31–6.78% |  |  | ([12](#_ENREF_12)) |
|  | BCP(not one kind) | 10–40% | 5–30% | 1–5% |  |  | ([25](#_ENREF_25)) |
|  | BCP(not one kind) | 54.22% (18.50–84.25%) carbohydrates 13.41 % ;(2.77–28.49 %) glucose;15.36% (4.9–33.48 %) fructose;4.25 % (0.05–9.02 %) sucrose | 21.30% (4.50–40.70%) | 5.31% (0.41–13.50%) Lipids |  | (0.69–213.20 mg GAE/g) | ([15](#_ENREF_15)) |
|  | BCP(Brazil) | Reducing sugars (up to 46%) | Proteins (up to 31%) | Lipids (up to 13%) |  | Up to 1.5 % | ([26](#_ENREF_26)) |
|  | BCP(Slovenia) | 13.2–27.8 % for fructose and 10.6–28.5 g %for glucose. |  |  |  |  | ([27](#_ENREF_27)) |
|  | BCP(not one kind) | 40–85% (W/W) of dry bee pollen | 14–30% (W/W) | 1–10% (W/W) |  |  | ([28](#_ENREF_28)) |
|  | BCP(Turkey) | 80.24 ± 0.836 | 15.69 ± 0.810 | 2.17 ± 0.038 |  | 14.42 ± 0.60 | ([29](#_ENREF_29)) |
|  | BCP (Malaysia) | 57.06 ± 2.09–58.89 ± 0.28 | 21.70 ± 0.08–23.33 ± 0.48 | 4.64 ± 0.04–5.95 ± 0.10 |  |  | ([30](#_ENREF_30)) |
|  | BCP(Ukraine) |  | 15.30 ± 2.09–28.06 ± 2.78 |  |  |  | ([31](#_ENREF_31)) |
|  | BCP(Colombia) |  | 23.1 ± 2.9 g | 3.4 ± 1.1 g |  | 3.2 ±1.0 mg Quercetin/g8.9 ± 3.1 mg Gallic acid/g | ([32](#_ENREF_32)) |
|  | BCP(India) |  | 57036.67 ± 14.83 (mg/mL)60780 ± 21.86 (mg/mL)33953.33 ± 4.83 (mg/mL) |  |  | 0.91 ± 0.04 GAE/100 gm0.99 ± 0.02 GAE/100 gm0.80 ± 0.03 GAE/100 gm | ([33](#_ENREF_33)) |
|  | BCP (European)(England) | (130 mg/g ± 63) | 629 mg/g ± 290 wet weight | 38 ± 2 mg/g |  |  | ([34](#_ENREF_34)) |
|  | BCP(Morocco) | (28.46% ± 0.994) | (12.81% ± 0.167) | (2.31% ± 0.574) |  | 14.88 ± 0.98 mg GAE/g1.67 ± 0.12 mg QE (quercetin equivalents)/g | ([35](#_ENREF_35)) |
|  | BCP(Malaysia) | Fructose (17‒23%) glucose (14‒16%) and sucrose (5‒6%) | Colombian (24%) and Italian (22%)Spanish sample (14%) | Spanish and Colombian (6%) Italian (2.5%) | Carotenoids 57, 25 and 221 µg/g for Spain, Italy, and Colombia BCP |  | ([36](#_ENREF_36)) |
|  | BCP(Brazilian) | 54.9–82.8 % | 7.9–32.2 % | 3.2–13.5 % |  | (6.5–29.2 mg GAE/g)(0.3–17.5 mg QE/g) | ([37](#_ENREF_37)) |
|  | BCP(Korea) |  | 17.2 ± 0.18–26.8 ± 0.07% | 3.1 ± 0.10–12.2 ± 0.04% |  |  | ([38](#_ENREF_38)) |
|  | BCP | 90% of total sugarsFructose and glucoseaverage contents ranged from 15.53–33.48 %13.59–27.69 % |  |  |  |  | ([39](#_ENREF_39)) |
|  | BCP (Turkey) |  |  | 3.37 ± 0.02%–6.85 ± 0.02% | 24.11 ± 0.09–98.62 ± 0.02 Carotenoidcontent (mg/g) | TPC: 434.17 ± 0.01–719.58 ± 0.01 %  | ([40](#_ENREF_40)) |
|  | BCP(Greece) |  |  |  |  | 15.2 ± 0.4 to 60.2 ± 2.0 (mg GAE/g extract)6.0 ± 0.3 to 57.6 ± 2.0 (mg QE/g extract) | ([41](#_ENREF_41)) |
|  | BCP(Turkey) |  |  |  |  | 3.9 and 9.2 mg GAE/g- 1.2–1.9 mg CAE/g  | ([42](#_ENREF_42)) |
|  | Honey(Brazil)BCP(Brazil) | 215 ± 33–301 ± 169 (mg/g) | 45 ± 18–99 ± 9 (mg/g) | 2 ± 0–6 ± 1 (%) |  | 32 ± 9–136 ± 32 (mg GAEq/100 g);8 ± 2–55 ± 20 (mg QEq/100 g)6.9–21 ± 2 (mg GAEq/g);0.3–17 ± 5 (mg QEq/g); | ([43](#_ENREF_43)) |
|  | BCP (Brazil) |  |  |  |  | 33.73–75.60 mg GAE/g1.42–9.05 mg QE/g | ([44](#_ENREF_44)) |
|  | Propolis |  |  |  |  | 13–379 mg of quercetin equivalents (QE) per g68–500 mg of caffeic acid equivalents (CAE) per g | ([45](#_ENREF_45)) |
|  | Propolis(Lithuania) |  |  |  |  | 68.03–99.85 mg RUE/10 g/3.24–14.39 mg RUE/10 g | ([2](#_ENREF_2)) |
|  | BCP(India) |  |  |  |  | 15.50 ± 1.25–25.63 ± 1.42 mg GAE/g and 9.72 ± 0.28–15.61 ± 0.74 mg RE/g | ([46](#_ENREF_46)) |
|  | Maize BCP(Malaysia) | carbohydrates (44.30 ± 3.73) % | (17.16 ± 3.13) % |  (0.62 ± 0.06%) |  | 783.02 mg GAE/ 100 g and 1706.83 mg QE/100 g | ([47](#_ENREF_47)) |
| **Bee secretions** | BV |  | Melittin 52% of all apitoxin peptides |  |  |  | ([9](#_ENREF_9)) |
|  | BV(not mention) |  | 0.1 g mixture of peptides, enzymes, and nonpeptide components |  |  |  | ([48](#_ENREF_48)) |
|  | BV(not one kind) |  | Small proteins and peptides |  |  |  | ([49](#_ENREF_49)) |
|  | Beeswax(not mention) | MUD 1: 6.4 ± 1.0MUD 2: 0.5 ± 2.3 | MUD 1: 12.9 ± 0.2MUD 2: 2.3 ± 0.1 | MUD 1:11.0 ± 0.5MUD 2:46.1 ± 3.7 |  | MUD 1: 1435.66MUD 2: 432.66 mg GAE q/100 g | ([50](#_ENREF_50)) |
|  | RJ(not one kind) | Near 30% | 27–41% | 8–19% |  |  | ([51](#_ENREF_51)) |
|  | RJ(not one kind) | 10–16% (w/w) | 9–18% (w/w) |  |  |  | ([52](#_ENREF_52)) |
|  | RJ | (16%) | Proteins and amino acids (12.5%) | 5% |  |  | ([53](#_ENREF_53)) |
|  | RJ(Japan) | 15% | 18% | 3–6% |  |  | ([21](#_ENREF_21))([54](#_ENREF_54)) |
|  | RJ(not one kind) | 7–18% w/w | 9–18% w/w | 3–8% w/w |  |  | ([55](#_ENREF_55))([56](#_ENREF_56)) |
|  | RJ(Lithuania) |  |  |  |  | 16.44–23.14 mg RUE/10 g/10.34–17.19 mg RUE/10 g | ([2](#_ENREF_2)) |
|  | RJ(not one kind) | 7.5–16% |  |  | Wax (5–6) %; steroids (3–4) %;phospholipids (0.4–0.8) % | Phenolic acids (4–10) % | ([57](#_ENREF_57)) |
|  | RJ(not one kind) |  |  | 7–18% |  |  | ([58](#_ENREF_58))([59](#_ENREF_59)) |
| **Bee ecological bodies and hives** | Bee pupae(Scotland) | (20.34%)total sugar (0.73%) | (46.21%) | (26.09%) |  |  | ([17](#_ENREF_17)) |
|  | Honeybee larvae(Japan) |  |  |  |  | 51.44 ± 2.77 total phenolic content (mg GAE/g)2.47 ± 0.23 TFC (mg RE/g) | ([60](#_ENREF_60)) |
|  | Honeybee larva(Japan) | 30.3% | 50.1% | 13.5% |  |  | ([61](#_ENREF_61)) |
|  | Larvae(Korea) | 46.1±1.73 | 35.3±2.09 | 14.5±0.15 |  |  | ([62](#_ENREF_62)) |
|  | Pupae(Korea) | 34.3±0.24 | 45.9±0.63 | 16.0±0.24 |  |  |  |

**Footnotes: BB**=Bee Bread; **BCP**=Bee Collected Pollen; **BV**= Bee Venom; **RJ**=Royal Jelly; **RUE**= rutin equivalent; **GAE**= Gallic Acid Equivalents; **QE**= Quercetin Equivalents; **RE**= Rutin Equivalents; **TFC**= Total Flavonoid Content; **TPC**= Total Phenolic Content; **CAE**=Caffeic Acid Equivalents;

**STable 2 The characteristics of each drying method.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Bee products** | **Drying technology** | **Conditions and achieve** | **Models and parameters** | **Advantages and disadvantages** | **Ref** |
| BCP(Turkey) | Hot air chamber | * the highest sensory scores obtained at 40 °C
* at 45, 50, 55, and 60 °C retained better quality
 | - | * A shorter processing time
* Lower risk of microbial contamination
* More effective
* Better control
* Applied in many industrial drying applications
 | ([63](#_ENREF_63)) |
| BCP(Colombia.) | Solar drying | * The average temperature was 50 °C
* air-flow speed of 2 m/s
 | - | * Generates energy savings Reduce the carbon footprint of the process
 | ([64](#_ENREF_64)) |
| BCP(Colombia) | Hot air drying | * The most adequate temperature was at 60 °C
* A marked increase in flavonoids, phenolics, and antioxidant activity
* A loss of carotenoids Structure slight degradation
 | - | * modify the microstructure of the exine
* Nutritional compounds would be more available
 | ([65](#_ENREF_65)) |
| BCP(Russian) | Cyclic convective drying | * The rational circulation speed range 2.2–2.5 m/s;
* air temperature 40–42 °C
 |  | * preserve the biologically active properties
 | ([66](#_ENREF_66)) |
| BCP(Italy) | Freeze-drying (FD)(using a lyophilizer Heto PowerDryLL1500) | * condensation chamber temperature was −115 °C,
* full vacuum.
* treated for 270, 420, or 540 min,
 |  |  | ([67](#_ENREF_67)) |
| RJ(Viet Nam) | FD | * optimal temperature was 20.58 °C,
* optimal pressure was 0.411 mmHg
* freeze time was 18.283 h
* final product reached the minimum 6.32 kWh/kg,
* The residual water content 4.19% under 4.5% (< 4.5%);
* Loss of protein, carbohydrate, lipid, mineral salts, 10-HAD, vitamin B5, free fatty acids,
* viscosity reached the minimum
 | * Using quadratic orthogonal experimental planning method

  |  | ([68](#_ENREF_68)) |
| RJ(Italy) | FD | * At −50 °C for 24 h
* Furoins content was higher in the freeze-dried RJ after both 6 and 12 months
 |  | * maintains the natural characteristics without damage or denature the thermolabile components
 | ([69](#_ENREF_69)) |
| RJ(Viet Nam) | FD | * The optimal temperature of the FD chamber was 24.35 °C
* The optimal pressure was 0.368 mmHg
* The optimal time of the FD process was 19.225 h
* After FD 3.51 under 4.5%, with the minimum value of the loss of nutrition
 | * Mathematical model of the residual water content
* Mathematical model of the total protein loss
* Mathematical model of the carbohydrate loss
* Mathematical model of the loss of lipid
 | - | ([70](#_ENREF_70)) |
| BCP (Turkey) | Infrared radiation drying | * Sample treated at different power levels 50, 62, 74, and 88 W.
* surface morphological changes
* quality characteristics retained better at 50 W
 | - | * Decrease the drying time
* with high-quality
* high energy efficiency
* uniform temperature in the dried product
 | ([71](#_ENREF_71)) |
| BCP(Italy) | FD and microwave-assisted drying (MWD) | * condensation chamber temperature was −115 °C
* At full vacuum.
* FD treatment for 9 h,
* The residual water content was 6.0%,
* The absolute pressure was 50 mbar.
* 150 W MW treatment for 30 min
 |  |  | ([72](#_ENREF_72)) |
| BCP(Brazil) | Infrared heating-assisted fluidized bed dryer | * Conventional drying at 35, 45, and 55 °C
* velocity equal to minimum fluidization velocity
* radiation intensity at 100, 400, and 700 W/m2 without heating the air
* 52% energy saving achieve using the IR heating-assisted fluidized bed dryer.
 | * Moisture diffusion model

XR: moisture ratio;* Kinetics of color
 | * Prevents browning reactions
* Avoids color degradation
 | ([73](#_ENREF_73)) |
| BB(Russia) | Convection drying method, |  |  | * High energy intensity of the process
 | ([74](#_ENREF_74)) |
| BB(Russia) | Vacuum method, |  |  | * High cost of equipment
 | ([74](#_ENREF_74)) |
| BB(Russia) | convective and infrared drying |  | COMSOL Multiphysics software* model of drying a porous body
 | * Reduce the processing drying time and energy intensity
 | ([74](#_ENREF_74)) |
| BCP(Turkey) | MWD  | * 300, 450, 600, and 900 W power
* 900 W created considerable degradation, nearly 26–28%, of vitamin E
 |  |  | ([29](#_ENREF_29)) |
| BCP(Italy) | MWD | * 50 mbar; MW power was 150 W; the exposure time was 30 min
* The residual water content was 6.4%, 10.3%, and 8.2% (chestnut, willow, and ivy pollen)
 |  | * Minimum affect the content of the flavonoids, complex B vitamins, and/or unsaturated lipids
 | ([75](#_ENREF_75)) |
| BCP(Turkey) | Microwave-assisted vacuum drying (MW-VD) | * 300, 450, 600, and 900 W power
 |  | * Higher reduction in antioxidant compounds (tocopherols)
* No substantial change in total phenols and flavonoid content of fresh bee pollen
 | ([29](#_ENREF_29)) |
| BCP(Turkey) | Hot-air drying (HAD) | * Air velocity of 0.54 m/s
* provided the best preservation of vitamin C at 35 °C
* An average loss ranging between 12.9 and 29.2% in vitamin E content
 |  | * Vitamin E, beta-carotene, and vitamin C loses during the heating
 | ([29](#_ENREF_29)) |
| BCP(Turkey) | Vacuum drying (VD) | * 300, 500 mbar
 |  |  | ([29](#_ENREF_29)) |
| BCP(Turkey) | FD | * Vacuum pressure of 0.1 mbar
* Vitamin E, total phenolic content, and TEAC values were similar
 |  | * The nutrition did not alter after FD
 | ([29](#_ENREF_29)) |
| BCP(Italy) | FD | * The temperature in the condensation chamber was −115 °C,
* full vacuum
* The residual water content was 6.0%, 6.3%, and 7.5%(chestnut, willow, and ivy pollen)
 |  | * minimum affect the content of the flavonoids, complex B vitamins, and/or unsaturated lipids
 | ([75](#_ENREF_75)) |
| BCP(Turkey) | low temperature high velocity (LTHV)-assisted fluidized beddrying | * 4, 10, 24, and 40 °C, ~40–50 humidity (%) and 6 m/s air velocity
* The cooling and heating unit was controlled with a thermostatic sensor connected
 | * Logarithmic (Logarithmic (asymptotic)
 | * Applied in the food industry
* preserve the quality of the perishable and semi-dried food product at low temperature
* minimize the lipid oxidation,
* minimize the texture, color, protein, and sensory quality lost
 | ([76](#_ENREF_76)) |
| BCP(Turkey) | Microwave drying | * 180, 360, 540, 720, and 900 W microwave power
* Drying time was shortened by 94% when increased from 180 to 900 W
 | * The moisture contents of the BCP

Arrhenius type equation | * Microwave energy speeds up the drying process
* energy saving, and drying with smaller dryer sizes
* Shorten drying time,
* retain nutritional value
* improve the final quality of dried products
 | ([77](#_ENREF_77)) |
| BCP(Turkey) | Hot-air (HAD) and vacuum (VD) | * (300, 500 mbar) drying at 35, 50 and 65 °C,
* A higher retention of enzyme activity, was observed at 50 °C
 |  |  | ([78](#_ENREF_78)) |
| BCP(Italy) | Classic hot air drying (HAD) | * A temperature of 32 °C for 24 h in the NTW100 cool-air dryer
* Residual water was 7%,
 |  | * produce Maillard’s compounds after drying
 | ([75](#_ENREF_75)) |
| BCP(Turkey) | MWD and microwave-assisted vacuum drying (MW-VD) | * (500, 675 mbar) at 300, 450, 600, and 900 W power
* A greater reduction was observed in DN of samples at 600 and 900 W
* Proline and HMF content were affected by the treatment power
 |  |  | ([78](#_ENREF_78)) |
| BCP(Turkey) | FD |  |  | * preserve the bioactive compounds and biological properties
 | ([78](#_ENREF_78)) |
| BCP(Italy) | MW-VD | * 50 mbar for some minutes
 |  | * Reduces the water content without thermally deteriorating important bioactive compounds
 | ([79](#_ENREF_79)) |

**Footnotes: BCP**=Bee Collected Pollen; **BB**=Bee Bread; **RJ**= Royal Jelly; **FD**=Freeze-drying; **HAD**=Hot-air drying; **MW-VD**=Microwave-assisted Vacuum Drying; **VD**=Vacuum Drying; **LTHV**=Low Temperature High Velocity; **MWD**=Microwave-assisted Drying; **TEAC**= Trolox Equivalent Antioxidant Capacity; **HMF**=Hydroxymethylfurfural; **10-HAD**=10-hydroxy-decenouc acid; **IR**= Infrared

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