Spray drying of fruits juice formulations of *Ananas cosmosus* L. *and Balanites aegyptiaca* : antihyperglycemic activity

.

ABSTRACT

Background: *Balanites aegyptiaca* is commonly used in folk medicine as antihyperglycemic agent.
Objective: Fruit juices from pineapple (*Ananas cosmosus* L), *Balanites aegyptiaca* and a blend after being encapsulated by spray dried with 10% maltodextrin, were examined for their physicochemical and antihyperglycemic properties.
Methods: Three different juice powders had been produced using spray dryer. The antihyperglycemic activity in glucose overloaded hyperglycemic rats has been evaluated.
Results: The juice powders had moisture contents ranging from 2.96 to 3.73% (dry basis). The fruit juice powders hygroscopicity varied between 14.44 and 15.38 g/100 g of juice powder samples. There were notable differences in the antihyperglycemic effects of the spray-dried juice samples on Wistar rats. Blood sugar levels were significantly ($P<0.05$) lower in the Wistar rats batch administered with reconstituted Balanites juice and glibenclamide at T_{90min} compared to the Normal control batch (4.77% and 29.44% respectively). Comparing the blood sugar levels of positive control (CP), Balanites, and Pineapple + Balanites animals to those of negative control (Cneg) animals and animals given pineapple juice, a substantial ($P<0.05$) decrease was noted.
Conclusion: The findings indicate that encapsulation by spray drying of pineapple juice with *Balanites aegyptiaca* fruits can be encouraged to be processed by fruit processing industries because the resulting juice powders have good antihyperglycemic properties.

Keywords: Spray-dried juice, Pineapple, Balanites aegyptiaca, antihyperglycemic activity

1. INTRODUCTION

Balanites aegyptiaca (L.) Delile (Family: Zygophyllaceae) is an unused fruit yielding tree native to Africa and distributed in subtropical and tropical regions of Africa. Both ripe and unripe fruits are edible and are referred to as "desert dates" in popular culture. The fruits are processed to make liquor and beverages [1-2]. Gad et al.[3] demonstrated the antidiabetic activities of fruit extracts (1.5 g/kg body weight) to diabetic induced rats with streptozotocin (STZ) and examined the amount of glycogen in the liver and kidney as well as some important enzymes of liver related to the metabolism of carbohydrates. Five times as much blood glucose was raised, levels of serum insulin were reduced by 80%, the value of liver glycogen content was decreased by 58%, and kidney glycogen content has been increased by seven times when streptozotocin STZ (50 mg/kg body weight) was administered to rats. In the case where fruit extract was oral administered to rats, glucose-6-phosphatase liver activity was considerably reduced and serum glucose levels were lowered by 24% [2].

In terms of tropical fruit output, pineapple (*Ananas cosmosus* L., family Bromeliaceae) ranks second globally with an estimated 28.3 million tons produced worldwide in 2018, according to estimates from the Food and Agriculture Organization of the United Nations. Cameroon shown a production of 312192.17 tons in 2021 [4]. The pineapple is a fruit that grows in tropical and subtropical areas and is consumed in a variety of ways all over the world, such as dry goods, juices, canned goods, and fresh fruit. The hypoglycemic and hypolipidemic properties of the ethanolic extract of Ananas comosus (L.) leaves were assessed [5-6]. Pineapples are used in the kitchen to make juices, jams, ice cream, and other treats in addition to being eaten fresh. Fresh fruit is challenging to carry due to the short shelf life of ascorbic acid-rich juice. Even if there are a lot of pineapple products available, the food business is constantly developing new pineapple goods. The novel product will assist pineapple growers by increasing demand for fresh pineapple, hence reducing losses from enzyme reactions, pesticides, and bacteria during the harvest season. Different processes of dehydration, including freeze drying, sun drying, spray drying, vacuum during, and oven drying, can turn fresh fruit into dry particles. Spray drying is a widely used technique for drying suspensions, which are solutions of heat-sensitive goods that are exposed to high temperatures for brief periods of time (usually a few seconds) [7-8].

Many powdered items can be produced using spray drying; however, fruit juices usually require the addition of carrier agents during the drying process, which may be a drawback in some circumstances [4]. Maltodextrin [$(C_6H_{10}O_5)_n.H_2O$] is one of the most used carrier agents in the drying of products in spray dryers. However, there is a drawback to the addition of maltodextrin: it can impact those with diabetes because it raises the product's carbohydrate content [10].

Diabetes is a disease characterized with elevated glucose levels in blood, leading to major complications such as diabetic neuropathy, nephropathy, retinopathy and cardiovascular disease [11]. With its high incidence, morbidity, and mortality, diabetes is the third leading cause of death in the world, behind cardiovascular and cancer diseases [12]. Between 2013 and 2035, the number of individuals with diabetes worldwide is predicted to rise from 382 to 592 million due to a variety of causes, including aging, a sedentary lifestyle, poor eating habits, and obesity [13]. Treatment options now in use, including as insulin therapy and oral hypoglycemics, have numerous drawbacks that restrict their usefulness. Phytotherapy has a long history of usage in treating a variety of conditions, including diabetes [14]. Moreover, numerous studies have been conducted in an effort to find new, naturally occurring antidiabetic drugs that are both cost-effective and have few side effects while also enhancing pancreatic beta cell function and increasing beta cell density. The discovery of novel bioactive compounds with several medicinal qualities, such as hypoglycemia and hypolipidemic effects and the ability to scavenge free radicals, is largely attributed to natural metabolites [15]. The challenge will be to consumed natural juice and maintain the blood glycemic level.

Many studies are available in the literature about the use of the spray dryer to obtain powdered fruit pineapple juice [8,10,16-17]. However, to the best of our knowledge there are no studies about spray dried pineapple-balanites fruits juice with antihyperglycemic properties study. Therefore, the objective of this work was to developed powder from pineapple together with *B. aegyptiaca* fruits juice so that it can be consumed after reconstitution in water without excluding diabetics showing a hygienic diet.

2. MATERIAL AND METHODS

2.1 Materials

2.1.1 Raw material

Fruits from the local fruit market of Ngaoundere were used for the study, including freshly harvested, completely matured pineapples (*Ananas cosmosus*) and balanites (*Balanites aegyptiaca* (L.) Delile). Maltodextrin (CAS 950-36-6) manufactured by Anhui Puya Biological Technology CO.,Ltd, China, was used as a carrier agent in spray drying.

2.1.2 Animals

For the current research, the Wistar male strain rats (150g to 200 g) were purchased from the Pasteur Institute in Yaoundé (Cameroon) and acclimatized at the Department of Biological Sciences, Laboratory of Medicinal Plants, Health and Galenic Formulation, University of Ngaoundéré (Cameroon). The animals were kept in rooms with controlled room temperature (24±2 °C) and free access to tap water and food provided by National Veterinary Laboratory (LANAVET), Garoua, Cameroon. All experimental procedures were approved by the institutional ethics committee of the Department of Biological Sciences of the University of Ngaoundere (ECDBSUN 01/15/2015/UN/FS/DSB).

2.2 Methods

2.2.1 Preparation of fruit juices

Pineapple fruits were cleaned with water to remove dirts, peeled, cut and juice extracted using juice extractor (Moulinex Blender Mixeur; Faciclic Steel; Inox -LM320A10, 550 W). A muslin cloth filter was used to extract the pineapple fruit juice and the juice with total solid content of 14.5 g/100 g (w/w), 13 °Brix, pH 3.76 had been obtained and stored at -18° C until use. Preparation of Balanites fruits juice had been done according to methods described by Gad et al [3]. The epicarps of 500g of the fruits were removed, and then the mesocarps of the fruits were scraped off and extracted with water (70 °C) for 4 h. Fruit juice was obtained by filtering through muslin cloth and juice with total solid content of 12 g/100 g (w/w), 14 °Brix, pH 4.35 had been obtained and stored at -18° C until use.

2.2.2 Spray drying method of fruits juice

Spray drying of juice was performed in a co-current small scale spray dryer (TFS-2LS SS304), with two-fluid nozzle with orifice 0.7 mm in diameter, operating at: inlet air temperature of 175 °C; feed flow rate of 500 mL/h; air flow rate of 73.5 m^3/h. To achieve this, all the two juices were diluted with distilled water to get a uniform Total Solid Content. The feed samples were obtained by addition of maltodextrin to respective pineapple and *Balanites* fruit juices. The third feed was made up with mixture of pineapple and *Balanites* juice with maltodextrin. The three different juice powders obtained were packed into plastic bags.

2.2.3 Analytical methods

2.2.3.1 Moisture content of spray dried juices

Moisture content of the powder sample was determined according to AOAC method [18]. Two grams of powder were weighed, and they were dried at 70 °C until constant weight. Samples were studied in triplicate and the mean has been determined.

2.2.3.2 Hygroscopicity of spray dried juices

Hygroscopicity of different powders obtained was determined following the method described by Muzaffar et al.[19] with some modifications. One gram sample of each powder was kept at 25 °C in a desiccator with a saturated NaCl solution (75.29% Relative Humidity, RH). Samples were weighed after a week, and hygroscopicity was calculated as g of absorbed moisture per 100 g of dry solids.

2.2.3.3 Antihyperglycemic effect of reconstituted powder juices in rats made hyperglycemic by glucose overload

Antihyperglycemic activity was studied in glucose overloaded hyperglycemic rats by the modified method of Jarald and al. [11] . To do this, thirty (30) male rats were non-water fasted for 12 h and then divided into 6 groups of 5 rats each. Immediately after distribution, the initial blood glucose levels of the rats were taken at time T_{0min}. The animals were force-fed in the following manner as soon as blood glucose levels were determined using an Onetoch-ULTRA glucometer and test strips. To do this, a small cut was made at the end of the rat tail, the first drop of blood was eliminated and the second placed on the reactive area of the strip previously mounted on the glucometer.

- Group 1 (Normal Control, CN) was given 10 milliliters per kilogram of body weight of distilled water;

- Group 2 (Negative Control, CNeg) received distilled water at a volume of 10 ml/kg body weight;

- Group 3 (Positive Control, CP) received Glibenclamide at a dose of 0.3 mg/kg body weight;

- Group 4 (Test Batch 1, Ananas) received reconstituted Pineapple juice at a dose of 250 mg/kg;

- Group 5 (Test Batch 2, Balanites) received reconstituted Balanites juice at a dose of 250 mg/kg;

- Group 6 (Test Batch 3, Ananas + Balanites) received the reconstituted of mixture of Pineapple and Balanites juices at a dose of 250 mg/kg.

Ninety minutes (90 min) later, the animals blood sugar has been evaluated ($T_{90\ min}$). Subsequently ($T_{90\ min}$), 3 g/kg of D-glucose were force-fed to the animals (except the CN batch). Blood sugar levels were then assessed every 30 minutes for 2 hours (T_{120min}, T_{150min}, T_{180min} and T_{210min}).

2.2.4 Statistical Analysis

The software Statgraphics Centurion XVI was used to perform the statistical analyses of experimental results. A Duncan's test was used to determine whether there was a significant difference between the results. $P < 0.05$ was considered significant.

3. RESULTS AND DISCUSSION

3.1 RESULTS

3.1.1 Moisture content and Hygroscopicity of powder juices

Table 1 showed that for three powders produced, moisture content of juice powder varied from 2.96 to 3.73% (dry basis), formulations resulted in moisture contents lower than 5%, a characteristic limit to water content proposed for spray dried products [20]. Jittanit et al. [16] reported moisture content values slightly lower than those observed in the present work.

Table 1. Moisture content and hygroscopicity of powders produced

	Powder of Pineaple	**Powder of Balanites**	**Powder of Pineaple+Balanites**
Moisture content (%)	3.73±0.87^{a*}	2.96±0.39 ^{a*}	3.14±0.72 ^{a*}
Hygroscopicity (%)	14.44±1.38^{a*}	15.38±0.77^{a*}	14.73±1.86^{a*}

Data are means ± standard deviations (n = 3). Values in the same line with different letters are significantly different (p < 0.05).

The hygroscopicity values of powder developed varied from 14.44% to 15.38%. According to Huppertz [21] and Zotarelli et al [22], powders with hygroscopicity between 15 and 20% (at 75% of RH) are highly hygroscopic. High hygroscopicity could lead to a loss of powder properties during storage. Moreover, we could observe a difficult reconstitution of the powders during use. The physical characteristics of the spray-dried powder are crucial and are primarily determined by a number of operational factors, including feed flow, nozzle type, nozzle pressure, and air flow and temperature. The concentration of the wall materials employed in the spray drying process has a significant impact on the physical characteristics, including surface area, reconstitution, and particle size. Higher maltodextrin concentrations were also found to produce powders that were less hygroscopic, according to the literature [10,20, 23].

3.1.2 Antihyperglycemic activity of reconstituted powder juices in glucose overloaded hyperglycemic rats

During this study, we noted that at T_{0min} there was no significant variation (P>0.05) in blood sugar levels in all treated animal groups compared to normal control animals (Fig. 1).

Compared to Normal Control (CN) batch, the administration of reconstituted *B. aegyptiaca* juice and glibenclamide in rats at T_{90min} (after administration of 3g/kg of D-glucose) resulted in a significant decrease (P<0.05) in blood sugar levels (4.77% and 29.44% respectively). However, the animals in the CNeg batch and those treated with the reconstituted pineapple juice with *Balanites* showed no significant variation (P>0.05) in their blood sugar levels compared to the normal control (CN).

During T_{120min}, T_{150min} and T_{180min}, and T_{210min} it is noted that there was no significant change (P>0.05) in blood sugar levels in positive control (CP), *Balanites* and Pineapple + *Balanites* rats compared to normal control (CN) rats. On the other hand, we note a significant decrease (P<0.05) in blood sugar levels in positive control CP, *Balanites* and Pineapple + *Balanites* compared to negative control (Cneg) animals (44.19%, 45.80% and 48.22% respectively) and animals treated with pineapple juice (55.06%, 57.48% and 60.55% respectively).

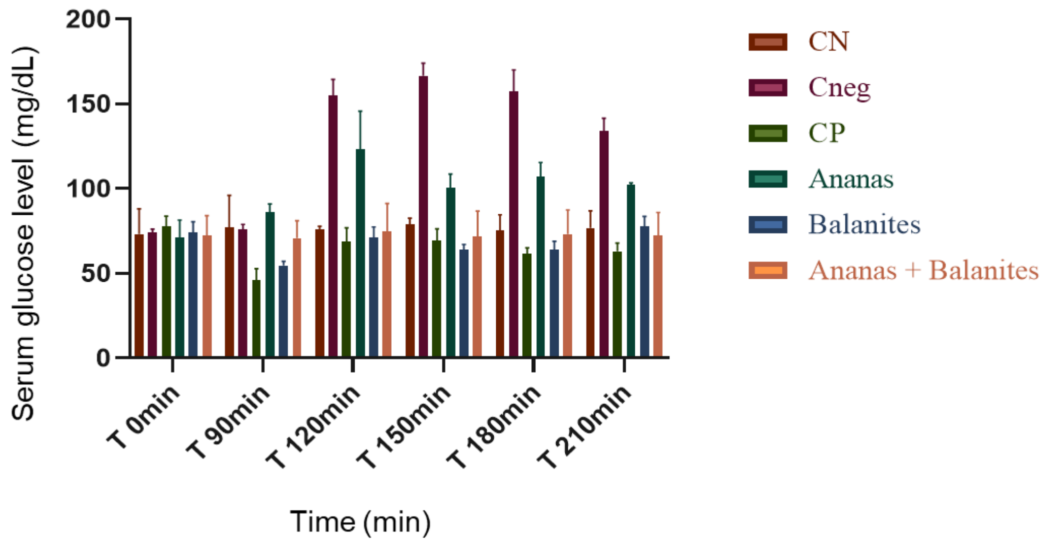

Fig. 1. Variation in blood sugar levels in animals treated with the different extracts depending on time.

3.2 DISCUSSION

The effect of glibenclamide, a typical drug used in this study, on glucose tolerance has been linked to increased pancreatic beta cell activity, which results in increased insulin secretion. According to Latha *and al.*[24], the mechanism underlying the antihyperglycemic activity of plant extracts and fraction involves an insulin-like effect, most likely by peripheral glucose consumption or increasing beta cell sensitivity to glucose, which leads to enhanced insulin release. The findings are consistent with the literature; reconstituted pineapple juice had little antihyperglycemic impact. In fact, literature only has antidiabetic activity information on pineapple leaf extracts were presented, no information about pineapple juice has been published [5-6].

The results presented in this study demonstrate that at T_0min, the blood sugar levels of all groups of animals are normal because they have not undergone any treatment. The non-increase in blood glucose at T_{90}min in the groups of animals would be due to the fact that the active substances containing in juice formulation administered (*Balanites* and glybenclamide) would have inhibited intestinal absorption of glucose. Likewise, according to a study carried out by Chikhi et al. [25] glibenclamide causes an insulin-secreting effect, thus leading to a drop in blood sugar. Furthermore, the increase in blood sugar at T_{120}min in the CNeg and Ananas rats would result in the fact that all of the D-glucose administered at T_{90}min would have been found in the blood of these animals in the absence of treatment.

From T_{120}min until the end of the experiment, we noted a significant decrease in the blood sugar levels of CP and Balanites and Pineapple+Balanites rats compared to Cneg animals. According to a study conducted by Elekofehinti [26], the aqueous extract of Balanites fruits is rich in saponins. Saponins exert their hypoglycemic effect through restoration of insulin response, enhancement of insulin signaling, increase in plasma insulin levels, induction of insulin release from the pancreas, increased expression of GLUT-4. In the case of this study, the hypoglycemic effect of Balanites would be due to these bioactive molecules contained in the aqueous extract of the juice.

4. CONCLUSION

From this study, it can be concluded from the results obtained that reconstituted pineapple juice has no antihyperglycemic effect. On the other hand, the reconstituted pineapple together with *Balanites* juices and *Balanites* juice alone have been shown to have antihyperglycemic effects starting at the 120th minute of the test. Thus, this study demonstrates the beneficial effects of juice (pineapple + *Balanites*) on diabetic patients, showing that these patients glycemia will be improved as a result of consuming this juice. Encapsulation by spray drying of juice from pineapple together with *Balanites* is a convenient method to process and dry pineapple juice into powder that has convenience of reconstitution just prior to consumption and also provides heath benefitting compounds with tolerance to diabetics.

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COMPETING INTERESTS

The authors report no conflicts of interest

AUTHORS' CONTRIBUTIONS

Conceptualization: [TTRK, TER]; Methodology: [TTRK, DTGE, TER]; Formal analysis and investigation: [TTRK, DTGE, CSSM]; Writing - original draft preparation: [TTRK]; Funding acquisition: [TTRK]; Resources: [CSSM, NRM]; Supervision: [NRM, NMB]. All authors read and approved the final manuscript.

CONSENT

Not applicable

ETHICAL APPROVAL

All experimental procedures on animals were approved by the institutional ethics committee of the Department of Biological Sciences of the University of Ngaoundéré (ECDBSUN 01/15/2015/UN/FS/DSB)

REFERENCES

1. Abdelaziz SM, Lemine FMM, Tfeil HO, Filali-Maltouf A, Boukhary AOMS. Phytochemicals, antioxidant activity and ethnobotanical uses of balanites aegyptiaca (L.) del. fruits from the arid zone of mauritania, Northwest Africa. Plants, 2020;9:9–12. https://doi.org/10.3390/plants9030401

2. Murthy HN, Yadav GG, Dewir YH, Ibrahim A. Phytochemicals and biological activity of desert date (Balanites aegyptiaca (L.) delile). Plants, 2021;10:1–22. https://doi.org/10.3390/plants10010032

3. Gad MZ, El-Sawalhi MM, Ismail MF, El-Tanbouly ND. Biochemical study of the anti-diabetic action of the egyptian plants fenugreek and balanites. Molecular and Cellular Biochemistry, 2006;281:173–183. https://doi.org/10.1007/s11010-006-0996-4

4.FAOSTAT. Crops and livestock products (2021). https://www.fao.org/faostat/en/#data/QCL (accessed on 10 October 2023)

5.Xie W, Xing D, Sun H, Wang W, Ding Y, Du L The efects of Ananas comosus L. leaves on diabetic-dyslipidemic rats induced by alloxan and a high-fat/high-cholesterol diet. Am J Chin Med 2005;33:95–105. https://doi.org/10.1142/S0192415X05002692

6. Bikash D, Waikhom SS, Kuntal M. A phytopharmacological review on Ananas comosus. Advances in Tradi Med 2021; p8 https://doi.org/10.1007/s13596-021-00563-w

7. Botha GE, Oliveira JC, Ahrné L. Quality optimisation of combined osmotic dehydration and microwave assisted air drying of pineapple using constant power emission. Food and Bioproducts Processing, 2012;90:171–179. https://doi.org/10.1016/j.fbp.2011.02.006

8. Teixeira, CCC, Teixeira GA, Freitas LAP. Spray Drying of Extracts from Red Yeast Fermentation Broth. Drying Technology: An International Journal, 2011;29:342-350, DOI: 10.1080/07373937.2010.497235

9. Adhikari B, Howes T, Bhandari BR, Troung V. Effect of addition of maltodextrin on drying kinetics and stickiness of sugar and acid-rich foods during convective drying: Experiments and modelling. Journal of Food Engineering, 2004;62:53–68. https://doi.org/10.1016/S0260-8774(03)00171-7

10. Bhagwat A, Bhushette P, Annapure US. Spray drying studies of probiotic Enterococcus strains encapsulated with whey protein and maltodextrin Beni-Suef University Journal of Basic and Applied Sciences 2020;9:33. https://doi.org/10.1186/s43088-020-00061-z

11. Jarald EE, Joshi SB, Jain DC. Antidiabetic activity of extracts and fraction of Zizyphus mauritiana. Pharmaceutical Biology, 2009;47:328–334. https://doi.org/10.1080/13880200902752488

12. Khairnar G, Mokale V, Khairnar R, Mujumdar A, Naik J. Production of antihyerglycemic and antihypertensive drug loaded sustained release nanoparticles using spray drying technique: Optimization by Placket Burman Design. Drying Technology, 2020;1-13. DOI:10.1080/07373937.2020.1825292

13. Derebe D, Wubetu M, Alamirew A. Hypoglycemic and antihyperglycemic activities of 80% methanol root extract of acanthus polystachyus delile (Acanthaceae) in type 2 diabetic rats. Clinical Pharmacology: Advances and Applications, 2020;12:149–157. https://doi.org/10.2147/CPAA.S273501

14. Acharyya, R.N., Mithila, S., Rani, S., Islam, M.A., Golder, M., Ahmed, K.S., Hossain, H., Dev, S., Das, A.K. Anti-allergic and Anti-hyperglycemic Potentials of Lumnitzera racemose Leaves: In vivo and In silico Studies. Proceedings of the National Academy of Sciences India Section B - Biological Sciences, 2023;93:147–158. https://doi.org/10.1007/s40011-022-01399-3

15. Tijjani H, Danyaro AD, Olatunde A, Kura AU. Antihyperglycemic activity of verbenone and L-arginine in nicotinamide-streptozotocin-induced diabetic mice: in vitro and in vivo studies.

Beni-Suef University Journal of Basic and Applied Sciences, 2022;1:94. https://doi.org/10.1186/s43088-022-00271-7

16. Jittanit W, Niti-Att D, Techanuntachaikul O. Study of spray drying of pineapple juice using maltodextrin as an adjunct. Chiang Mai Journal of Science, 2010;37:498–506.

17. Pasanna LT, Rao SA, Lakshmi VV, Sree YV. Process technology for production of spray and freeze dried pineapple powder. ~ 766 ~ Journal of Pharmacognosy and Phytochemistry, 2020;9:766–771. www.phytojournal.com

18. AOAC (2012) Official method of analysis of the association of the analytical chemists. Gaithersberg, MD: Author.

19. Muzaffar K, Dinkarrao BV, Kumarhttps P. Optimization of spray drying conditions for production of quality pomegranate juice powder Optimization of spray drying conditions for production of quality pomegranate juice powder. Cogent Food & Agriculture, 2016;76. https://doi.org/10.1080/23311932.2015.1127583

20. Fang Z, Wang R, Bhandari B. Effects of Type and Concentration of Proteins on the Recovery of Spray-Dried Sucrose Powder. Drying Technology, 2013;31:1643–1652 https://doi.org/10.1080/07373937.2013.770011

21. Huppertz T. Analytical Methods for Food and Dairy Powders. International Dairy Journal, 2012;27:103. https://doi.org/10.1016/j.idairyj.2012.07.001

22. Zotarelli MF, da Silva VM, Durigon A, Hubinger MD, Laurindo JB. Production of mango powder by spray drying and cast-tape drying. Powder Technology, 2017;305:447–454. https://doi.org/10.1016/j.powtec.2016.10.027

23. Jangam SV, Thorat BN. Optimization of Spray Drying of Ginger Extract, Drying Technology: An International Journal, 2010;28:1426-1434, DOI: 10.1080/07373937.2010.482699

24. Latha M, Pari L, Sitasawad S, Bhonde R. Insulin-secretagogue activity and cytoprotective role of the traditional antidiabetic plant Scoparia dulcis (Sweet Broomweed). Life Sciences, 2004;75:2003-2014. https://doi.org/10.1016/j.lfs.2004.05.012

25. Chikhi I., Allali H., Dib M. E. A., Medjdoub H., BoufeldjaT. Antidiabetic activity of aqueous leaf extract of Atriplexhalimus L. (Chenopodiaceae) in Streptozotocin-induced diabetic rats.AsianPac J Trop Dis. 2014; 4(3): 181-184.

26. Elekofehinti O. Saponins : Anti-diabetic principles from medicinal plants A review. Pathophysiology, 2015; 22:95-103.

ABBREVIATIONS

RH Relative Humidity
CN Normal Control
CNeg Negative Control
CP Positive Control
STZ streptozotocin