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CAULIFLOWER AND BROCCOLI FLORETTING MACHINE

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A b s t r a c t

Florets are the main edible parts of cauliflowers and broccoli, but stalks and leaves are also used in the production of vegetable soup mixes. In industrial processing lines, large cauliflower and broccoli inflorescences have to be separated into smaller florets with a diameter of 2 to 6 cm. Simple and inexpensive machines for floretting cauliflowers and broccoli, including devices that can be used in small-scale production, are in short supply on the market. Therefore, the aim of this study was to design a floretting machine composed of a load-bearing frame, a processing table, a crushing chamber and a horizontal conveyor. In the first stage of the process, one of the two conical knives is used to separate florets and leaves from stalks. The stalks fall into a container under the processing table, and the leaves are picked manually from the material on the table and are placed in a separate container. In the second stage, the separated florets are manually fed into the crushing chamber where larger florets are separated into smaller parts. The crushing

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chamber is composed of a rotating crushing roller and a fixed screen at the bottom. Florets that have been cut into the appropriate size pass through the screen and fall onto a conveyor belt under the crushing chamber. The quality of the floretting process can be inspected visually by the operator, and impurities or excessively damaged florets can be removed from the conveyor belt. In the final stage, the separated florets are transported to a container. The designed machine can be operated directly on the farm; therefore, the resulting produce is fresher than products that are transported and separated in a food processing plant.

Introduction

Cauliflower and broccoli are long-day plants whose production requires relatively low mean daily temperatures (15-20°C) and aerated soils with a high moisture content to promote high biomass yields and inflorescence development. These plants thrive on fertile and medium-heavy black soils, loamy sands and peat soils that are rich in humus, well aerated, and have a neutral to slightly acidic pH (FARNHAM, BJORKMAN 2011, SAVITA et al. 2014, ŁABANOWSKI 2016). Cauliflowers and broccoli have to be regularly irrigated when grown on light soils. These plants should not be grown in the same soil for more than 4 years or after other *Brassica* species (ŁABANOWSKI 2016).

Cauliflowers and broccoli are grown from seedlings that are produced in containers. In Central Europe, seedlings can be transplanted after around 5 weeks if planted in early spring or after 3-4 weeks if planted in summer and fall. Seedlings can be planted in early April provided that they have been cold-adapted to tolerate temperatures as low as -6°C. In most farms, land is divided into smaller plots, and successive batches of seedlings are planted at intervals of approximately 12 days to prolong the harvest and promote efficient use of labor and storage space (ŁABANOWSKI 2016). Cauliflowers and broccoli have high nutrient requirements and respond well to organic fertilizers (FARAHZETY, AISHAH 2013, SAVITA et al. 2014, FARZANA et al. 2016, SIMARMATA et al. 2016). Due to their high biomass yields, these plants require high rates of nitrogen fertilizer, supplemented with adequate amounts of phosphorus, potassium, magnesium and sulfur (KODITHUWAKKU, KIRTHISINGHE 2009, MADUMATHI et al. 2017, KAUR et al. 2020). Most cauliflower and broccoli varieties have a preference for relatively low temperatures (FARNHAM, BJORKMAN 2011, FARZANA et al. 2016), but high yields can also be obtained in years with hot summers if soil is kept consistently moist (70-75% of field water capacity). Water demand is highest directly after planting and during floret development. High rates of nitrogen fertilizers and abundant irrigation increase crop yields by promoting the formation of large and compact inflorescences. However, overwatering can negatively affect flavor, shelf life and suitability for freezing (SAVITA et al. 2014, ŁABANOWSKI 2016).

Cauliflowers and broccoli should be harvested when inflorescences are compact, properly formed and contain closed flower buds. Inflorescences are harvested together with thick fleshy stalks. Florets do not mature simultaneously, which is why cauliflowers and broccoli are harvested manually, and the plot has to be inspected several times within a given period of time. In most cases, field workers are distributed along rows with a specific width, and they inspect the rows and decide which inflorescences should be harvested based on their size and overall health (ŁABANOWSKI 2016, SERRANO, ROLLE 2018). Inflorescences harvested in the field contain several leaves and a part of the stalk. They are placed on a conveyor belt which can be connected to the tractor and moves directly in front of field workers. The conveyor belt carries inflorescences to the harvesting platform, where the crops are loaded into pallet containers. The harvesting platform has a shading canopy to protect the crops against the drying effects of sun and wind. In most cauliflower and broccoli varieties, when the main inflorescence is removed, lateral buds emerge on the sides of the stalk, and they can be harvested until the first frost. In summer, inflorescences are harvested as they mature, usually every 2-3 days, and they are harvested once a week in fall. Cauliflowers and broccoli are perishable vegetables that quickly lose their commercial value, which is why they should be harvested in the morning (when temperature is relatively low and humidity is high) on cloudy days (HODGES et al. 2006, ŁABANOWSKI 2016, SERRANO, ROLLE 2018).

Harvested cauliflower and broccoli inflorescences can be directly consumed, stored for 2-4 weeks or frozen. Large inflorescences have to be separated into smaller florets with a size that is appropriate for further processing, usually 2-6 cm in diameter (ŁABANOWSKI 2016). In industrial plants, florets are separated in large, expensive and highly complex processing lines that occupy a large area in dedicated facilities and are not affordable to many crop producers. A processing line costs even tens of thousands of Euros. Simple and inexpensive devices that could be operated directly on the farm are in short supply on the market.

Design requirements

As previously mentioned, the inflorescence is the main edible part of cauliflowers and broccoli. Inflorescences are sold as whole heads (for direct consumption) or are separated into florets (in processing plants). Stalks are also becoming increasingly popular, and when the tough outer layer is removed, diced stalks can be added to vegetable mixtures as a replacement for kohlrabi. Cauliflower and broccoli leaves also have high nutritional value. Dried, chopped and granulated leaves can be used as semi-processed products in vegetable soup mixes (SINGH et al. 2005, CHAKRABORTY, DATTA 2018, RAFIUDDIN et al. 2019, SHI et al. 2019, BERNDTSSON et al. 2020).

Harvested inflorescences rapidly lose moisture, which leads to wilting and discoloration. To minimize this risk, inflorescences should be relatively quickly separated into florets. In small farms, inflorescences are separated manually, which poses a significant challenge because manual floretting is a laborious process, and few workers are willing to perform this task.

In view of the above, the designed cauliflower and broccoli floretting machine should meet the following requirements:

– large inflorescences should be separated into small florets, where florets measuring 20-60 mm in diameter should be the predominant fraction;

– large inflorescences should be separated into three fractions: florets, stalks and leaves;

– florets should be separated with knives whose dimensions should be adapted to the diameter of stalks.

Cauliflower and broccoli stalks have a circular cross-section; therefore, florets should be separated by a knife with the shape of hollow truncated cone with a sharpened top edge. On average, cauliflower and broccoli inflorescences have a diameter of 10-25 cm and a height of 7-12 cm, and stalk diameter ranges from 2 to 5 cm (Kabiraj et al. 2017, de Souza et al. 2018, Giri et al. 2018). Two conical knives have been designed for the floretting machine: one with a diameter of 40 and 50 mm, and the other with a diameter of 50 and 70 mm. Both knives have the same height of 100 mm. The separated florets will fall into the crushing chamber, where oversized florets will be divided into smaller segments.

Structure of the floretting machine

A patent application for the designed cauliflower and broccoli floretting machine has been submitted to the patent office (Jadwisieńczak et al. 2020). The structure of the floretting device is presented in a schematic diagram in Figure 1. A load-bearing frame (*13*) on supports (*11*) is the main structural component of the proposed machine. The front part of the load-bearing frame consists of a processing table (*2*) with two differently sized knives (*3*) in the shape of a truncated cone with a sharpened top edge. The operator stands on a raised platform (*10*) by the processing table, and unprocessed vegetables are placed in a container (*9*) on the platform. The operator picks vegetables from the container, evaluates the size of the stalk and selects the appropriate knife for separating florets. An emergency stop button (*12*) for turning the machine off in the event of a malfunction is located within easy reach of the operator. The operator inserts the lower part of the stalk inside the opening in the selected knife and pushes the inflorescence downwards onto the knife. Successive florets are separated from the bottom up, and the operation is repeated until the last floret remains on the apex. The apical floret is separated by making

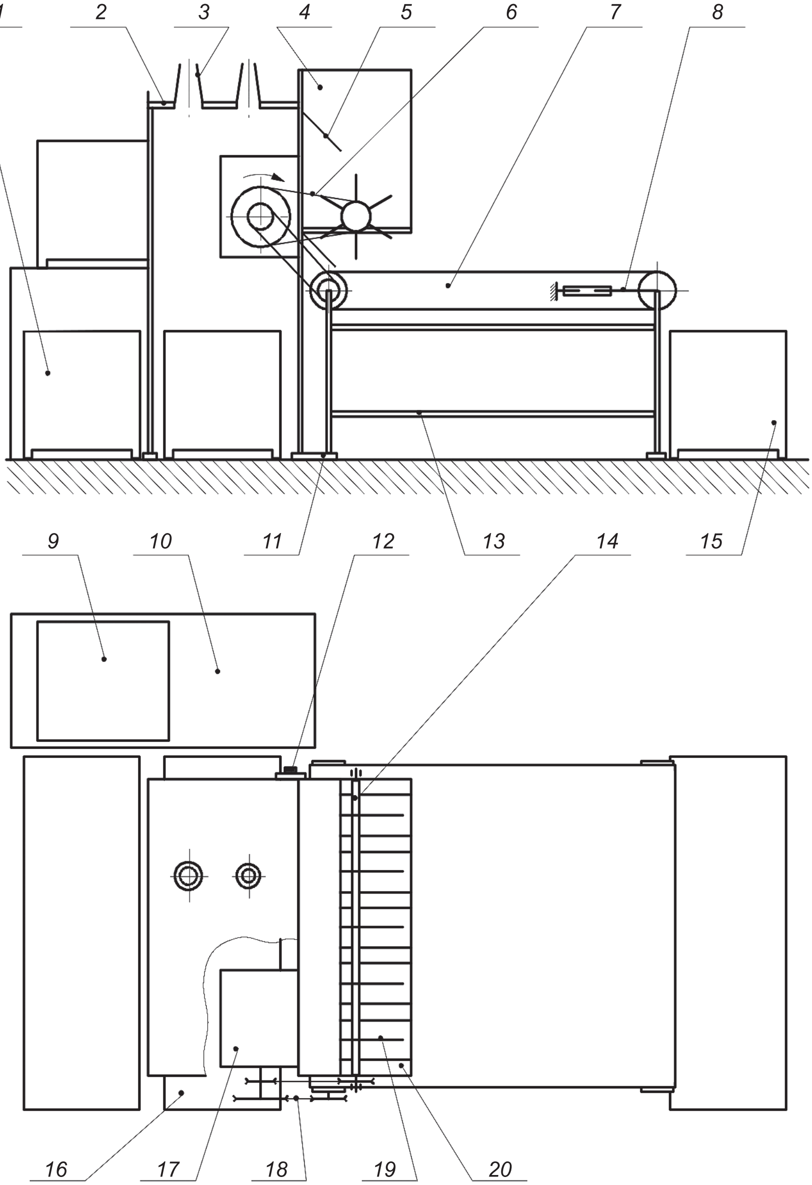

Fig. 1. Schematic diagram of the proposed cauliflower and broccoli floretting machine: *1* – waste container (e.g. for discarded leaves), *2* – processing table, *3* – floretting knife, *4* – hopper, *5* – inclined plane, *6* – V-belt drive of the crushing unit, *7* – horizontal conveyor, *8* – conveyor tensioner, *9* – container for unprocessed vegetables, *10* – platform, *11* – support, *12* – on/off switch, *13* – load-bearing frame, *14* – crushing roller, *15* – container for separated florets, *16* – container for separated stalks, *17* – electric motor, *18* – V-belt drive of the horizontal conveyor, *19* – cutters, *20* – screen at the bottom of the hopper in the crushing unit

a horizontal cut with an additional knife, such as a kitchen knife. The stalk falls into a container (*16*) under the processing table, and the separated florets and leaves are gathered on the table. In the first stage of the process, leaves are separated manually and are placed in the appropriate container (*1*). The remaining material is fed manually into the hopper (*4*) of the crushing unit. The crushing unit consists of a rotating crushing roller (*14*) with cutters (*19*) and a fixed screen at the bottom (*20*). The roller is positioned directly above the screen, and cutters are inserted into the openings in the bottom screen when the roller is set in motion. Large florets are crushed by cutters, and the separated fragments pass through screen openings. Vegetables are fed into the rear part of the crushing chamber via an inclined plane (*5*) to minimize product damage. A horizontal endless conveyor belt (*7*) with two pulleys is positioned under the bottom screen. The first pulley is the power drive, and the position of the second pulley and belt tension can be controlled with a tensioner (*8*). The conveyor belt and the crushing roller are powered by an electric motor (*17*) via two V-belts (*6* and *18*). The separated florets are transported to a container (*15*) at the end of the conveyor belt.

Prototype of a floretting machine

The prototype of the designed floretting machine (Fig. 2) was built at the Department of Food Processing Methods and Technology of the Łukasiewicz Research Network – Industrial Institute of Agricultural Engineering in Poznań. The floretting machine has the following dimensions: length – 260 cm, width – 80 cm, height – 180 cm. The load-bearing frame is made of X5CrNi18-10 stainless steel sheet with a thickness of 3 mm. The frame is supported by welded square tubes measuring 80×80 mm or 50×50 mm (Fig. 2*a*). The machine rests on polyamide wheels that are equipped with a mechanical brake. The remaining elements are made of profiled X5CrNi18-10 stainless steel sheets with a thickness of 1 to 5 mm, and they are connected by thread or weld joints.

The designed machine features a processing table with two differently sized conical knives, a crushing chamber with a crushing roller, bearing assembly and a removable screen, a conveyor belt for transporting separated florets, and a power drive system composed of an electrical motor and two V-belts. The machine is equipped with 4 containers, including 1 container for unprocessed vegetables and 3 containers for the processed plant parts (leaves, stalks and separated florets). The processing table is positioned at a height of 160 cm, and a raised platform is required to accommodate the operator and the container with unprocessed vegetables. The processing table (Fig. 2*b*) is a flat horizontal plate with two openings that accommodate differently sized conical knives.

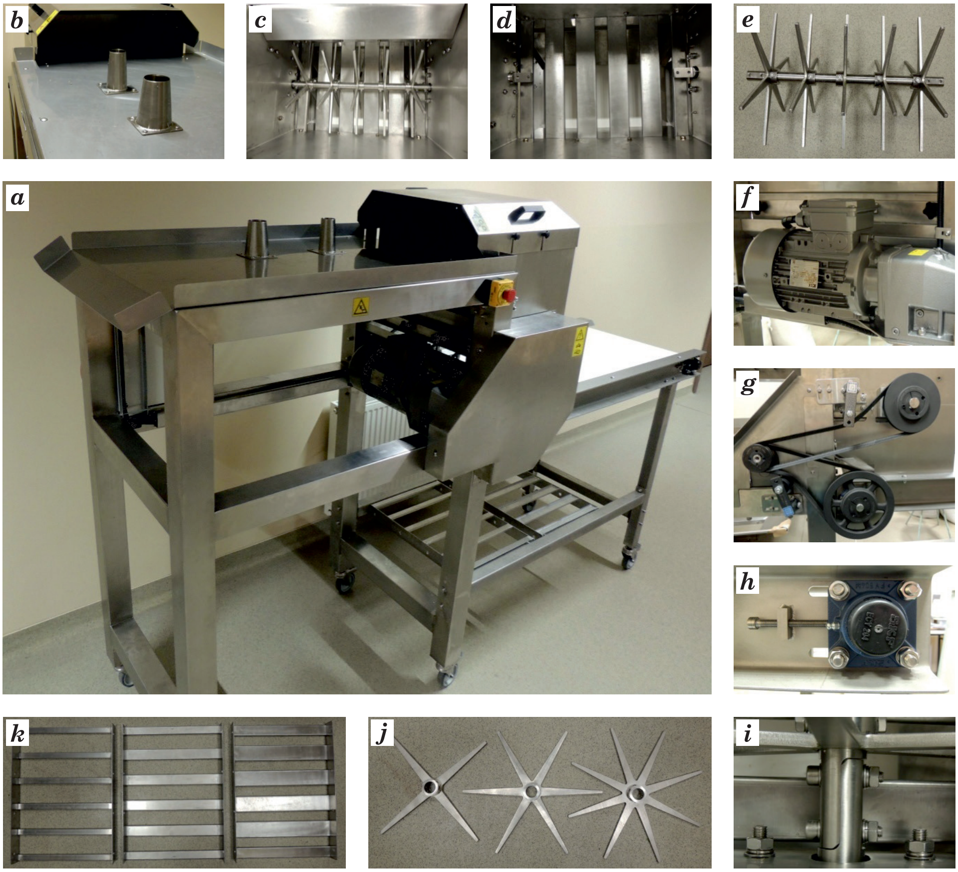

Fig. 2. Prototype of a cauliflower and broccoli floretting machine: *a* – general view, *b* – processing table with floretting knives, *c* – crushing chamber, *d* – screen at the bottom of the crushing chamber, *e* – crushing unit, *f* – electric motor, *g* – V-belt drives of the horizontal conveyor and the crushing unit, *h* – conveyor tensioner, *i* – assembly of crushing roller components, *j* – differently sized star-shaped cutters, *k* – screen with differently sized openings

The knives are made of 2 mm thick steel sheet. The knives have a sharp top edge, and the bottom edge is welded to square support plates in table openings. The support plates are mounted to the processing table with screws and can be replaced when worn or damaged.

The crushing chamber has a cover to protect the operator against rotating machine parts. The inlet of the crushing chamber is located on the side of the processing table, and it features an inclined plane (Fig. 2*c*) which directs florets to the rear part of the crushing unit. Small florets pass through the screen, whereas large florets are deposited on the rounded edges of screen openings (Fig. 2*d*) and are broken into smaller fragments by the crushing unit (Fig. 2*e*).

The machine is equipped with 3 interchangeable screens with 5 openings with a width of 40, 60 and 80 mm (Fig. 2*k*). The crushing roller is positioned above the screen, and it features centrally positioned cutters which are inserted into screen openings when the roller is set in motion. Cutters have the shape of 4-, 5- and 6-pointed stars (Fig. 2*j*) with a diameter of 385 mm and a thickness of 8 mm. Cutters are mounted to the crushing roller with bushings and screws. The drive shaft consists of three segments to facilitate the assembly and disassembly of star-shaped cutters. Two shaft segments are mounted on bearings in the load-bearing frame (Fig. 2*d*), and the third segment can be removed (Fig. 2*e*). When connected (Fig. 2*i*), the three segments of the drive shaft form the crushing unit with a pulley wheel at the end (Fig 2*g*). The crushing unit is powered by a 1.1 kW electric motor supplied with three-phase power via a power control box. The box is used to turn the machine on and off and control engine speed. In an emergency, power can be immediately cut off by pushing one of the two emergency stop buttons that are located on both sides of the machine. The motor shaft features two pulleys, one of which drives the crushing roller, and the other drives the conveyor belt (Fig. 2*g*). V-belts are tensioned by boomerang tensioners.

Separated florets fall on the conveyor belt and are transported to the container at the end of the conveyor. The quality of the floretting process can be inspected visually by the second operator, and impurities or excessively damaged florets can be removed from the conveyor belt. A visual inspection system was not designed to minimize construction costs which are estimated at EUR 1000-1500. Belt tension can be adjusted with two tensioners (Fig. 2*h*) on both sides of the conveyor.

Floretting process

Machine parameters are set, and the floret separation process consists of the following stages that are repeated for every inflorescence (Fig. 3):

– the operator manually picks an inflorescence from the container;

– the operator evaluates stalk size and selects an appropriately sized knife;

– the operator pushes the inflorescence onto the knife (the stalk is placed inside the opening of the knife), applies pressure, and separates successive florets from the bottom up until only the apical floret remains;

– the operator removes the apical floret with an additional knife (the stalk falls into a container under the processing table);

– the operator manually separates the leaves from the florets remaining on the processing table, and places the separated leaves in a container under the machine;

– the operator moves florets from the processing table to the crushing chamber;

– large florets are separated by the crushing unit;
– florets pass through screen openings onto the horizontal conveyor belt;
– the second operator visually inspects the separated florets on a moving conveyor belt and removes any impurities;
– processed florets are transported to the product container.

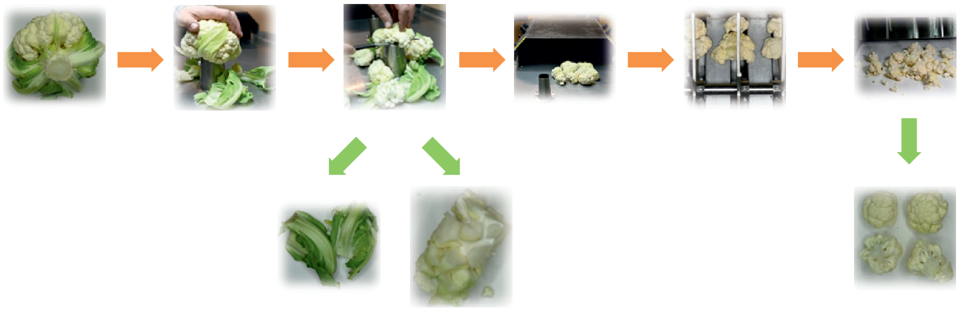

Fig. 3. Flowchart of the cauliflower and broccoli floretting process

Summary

The machine for cutting (floretting) cauliflower and broccoli is small in size and weight, and it is an efficient and compact device that minimizes workload and guarantees the production of high-quality semi-processed products. Hence, it can be operated by small producers. Cauliflower and broccoli florets that are separated directly on the farm are fresher than products that are transported and separated in the food processing plant.

A conical knife significantly increases the efficiency and yield of the separation process relative to manual floretting of cauliflower and broccoli. Inflorescences are cut into evenly sized florets by a crushing unit composed of a roller with star-shaped cutters and a screen with suitably sized openings. The separated florets are suitable for various applications in the food processing industry. Due to its lower manufacturing and purchasing costs, the proposed device is significantly cheaper than industrial floretting machines that are currently available on the market.

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References

Berndtsson E., Andersson R., Johansson E., Olsson M.E. 2020. *Side streams of broccoli leaves: a climate smart and healthy food ingredient*. International Journal of Environmental Research and Public Health, 17(7): 2406. https://doi.org/10.3390/ijerph17072406.

Chakraborty S., Datta S, 2018. *Promising nutritional and curative potentials of cauliflower leaves*. Indian Science Cruiser, 32(4): 53-61. https://doi.org/10.24906/isc%2F2018%2Fv32%2Fi4%2F176487.

Farahzety A.M., Aishah H.S. 2013. *Effects of organic fertilizers on performance of cauliflower (Brassica oleracea var. botrytis) grown under protected structure*. Journal of Tropical Agriculture and Food Science, 41(1): 15-25.

Farnham M.W., Bjorkman T. 2011. *Breeding vegetables adapted to high temperatures: a case study with broccoli*. HortScience, 46(8): 1093-1097. https://doi.org/10.21273/HORTSCI.46.8.1093.

Farzana L., Solaiman A.H.M., Amin M.R. 2016. *Potentiality of producing summer cauliflower as influenced by organic manures and spacing*. Asian Journal of Medical and Biological Research, 2(2): 304-317. https://doi.org/10.3329/ajmbr.v2i2.29075.

Giri H.N., Sharma M.D., Thapa R.B., Pande K.R., Khatri B.B. 2018. *Growth, yield and post-harvest quality of late season cauliflower grown at two ecological zones of Nepal*. Journal of Agriculture and Forestry University, 2: 119-126.

Hodges D.M., Munro K.D., Forney C.F., McRae K.B. 2006. *Glucosinolate and free sugar content in cauliflower (Brassica oleracea var. botrytis cv. Freemont) during controlled-atmosphere storage*. Postharvest Biology and Technology, 40(2): 123-132. https://doi.org/10.1016/j.postharvbio.2005.12.019.

Jadwisieńczak K., Konopka S., Duber-Skwarska O., Majkowska-Gadomska J. 2020. *Kruszarka do warzyw [Vegetable crusher]*. Patent application No. P.434342, Patent Office of the Republic of Poland, Warsaw.

Kabiraj J., Das R., Das S.P., Mandal A.R. 2017. *A study on cauliflower (Brassica oleracea var. botrytis) based intercropping system*. International Journal of Current Microbiology and Applied Sciences, 6(7): 2595-2602. https://doi.org/10.20546/ijcmas.2017.607.306.

Kaur P., Singh S.K., Kaur R., Sidhu M.K. 2020. *Response of different levels of nitrogen and spacing on growth and yield of cauliflower grown under central region of Punjab*. International Journal of Bio-resource and Stress Management, 11(4): 320-326. https://doi.org/10.23910/1.2020.2110.

Kodithuwakku D.P., Kirthisinghe J.P. 2009. *The effect of different rates of nitrogen fertilizer application on the growth, yield and postharvest life of cauliflower*. Tropical Agricultural Research, 21(1): 110-114. https://doi.org/10.4038/tar.v21i1.2592.

Łabanowski G. 2016. *Metodyka Integrowanej Produkcji Brokułu* [*Methodology for Integrated Broccoli Production*]. PIORIN, Warszawa.

Madumathi D.T.C., Reddy P.S.S., Reddy D.S. 2017. *Effect of planting density and transplanting time on growth and curd yield of broccoli*. International Journal of Horticulture and Floriculture, 5(4): 301-303.

RAFIUDDIN M., SWATHI Y., PRAKASH M., SUNEETHA W., KUMARI B. 2019. *Standardization and evaluation of cauliflower stalks incorporated phulkas*. International Research Journal of Pure and Applied Chemistry, 19(3): 1-6. https://doi.org/10.9734/irjpac/2019/v19i330114.

SAVITA J., CHOUDHARY A.K., NEGI M.S., KUMAR A. 2014. *Scientific cultivation of cauliflower (Brassica oleracea L. var. botrytis).* In: A.K. Choudhary, K.S. Rana, A. Dass, M. Srivastav (Eds.) *Advances in Vegetable Agronomy* (p. 67-78). Post Graduate School & Indian Council of Agricultural Research, New Delhi, India.

SERRANO E.P., ROLLE R. 2018. *Post-harvest Management of Cauliflower for Quality and Safety Aassurance. Guidance for Horticultural Supply Chain Stakeholders*. Food and Agriculture Organization of the United Nations, Rome, Italy.

SHI M., HLAING M.M., YING D., YE J., SANGUANSRI L., AUGUSTIN M.A. 2019. *New food ingredients from broccoli by-products: physical, chemical and technological properties*. International Journal of Food Science and Technology, 54(4): 1423-1432. https://doi.org/10.1111/ijfs.14111.

SIMARMATA M., SUSANTI L., SETYOWATI N. 2016. *Utilization of manure and green organic composts as alternative fertilizers for cauliflower production*. Journal of Agricultural Technology, 12(2): 311-319.

SINGH G., KAWATRA A., SEHGAL S. 2005. *Development and nutritional evaluation of products prepared from dried powder of cauliflower leaves*. Journal of Food Science and Technology, 42(2): 137-139.

SOUZA A.P. DE, SILVA A.C. DA, TANAKA A.A., SOUZA M.E. DE, PIZZATTO M., FELIPE R.T.A., MARTIM C.C., FERNEDA B.G., SILVA S.G. DA. 2018. *Yield and water use efficiency of cauliflower under irrigation different levels in tropical climate*. African Journal of Agricultural Research, 13(32): 1621-1632. https://doi.org/10.5897/AJAR2018.13186.