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Nozzles for Vegetable Washing

The drop spectra formed in the spray jet of various nozzles were tested on their energy and evaluated for their efficiency. Forming an efficient spray structure for vegetable cleaning is significantly defined by volume flow in combination with the nozzle distance. Through the collected experimental data from various nozzles, energetically optimal, cleaning-effective drop volume distribution of a spray jet was elaborated on, in order to optimise the spray disintegrating characteristics of the nozzles.

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Literature

Literature references can be called up under LT 03420 via internet http://www.landwirtschaftsverlag.com/landtech/local/literatur.htm.

Vegetable washing with nozzles must be performed carefully in a short time with as little fresh water and energy as possible. The relation between the different factors of influence on the jet spray structure and the jet effect at the impact surface were analysed by a standard testing method developed in the context of a basic research, in order to show the possibilities of optimising the nozzles as well as the washing process.

Materials and methods

In the following article, results obtained from the investigation involving two out of six selected washing nozzles are described. Nozzles with different flow rates were examined for water saving potential and thoroughness as well as gentle cleaning under conditions that are normal in vegetable washing in practice. The jet parameters of both nozzles were determined under varying operating parameters, at spray pressure (p) of 3, 5 and 8 bar, and at fixed nozzle distances (d) of 10 and 20 cm. An energetic analysis of the droplets formed in the jet spray was obtained.

A standardised examination procedure for the evaluation of the jet parameters of the nozzles with regard to their surface efficiency was developed; this was accomplished by a recording of the droplet impulse distributions in the jet spray and their effect along the radial jet dispersion [11].

spray pressure (bar)	spray width (mm)	spray depth (mm)	spray angle (measured at the impact surface) (°)	spray area A (mm^2)
1a. Agricultural nozzle LU 90-04, spray angle according to manufacturers recommendations: 90° ; a = 100 mm				
2,5	224	48	96,5	9687,1
5	256	16	104,1	5798,0
8	272	16	107,4	5967,9
Industrial nozzle 632.726, spray angle according to manufacturers recommendations: 90°				
2,5	144	16	71,5	2344,2
5	176	16	82,7	3729,1
8	176	16	82,7	3729,1
1b. Agricultural nozzle LU 90-04, spray angle according to manufacturers recommendations: 90° ; a = 200 mm				
2,5	416	80	92,3	35489,4
5	480	48	100,4	21662,6
8	496	48	102,3	22376,2
Industrial nozzle 632.726, spray angle according to manufacturers recommendations: 90°				
2,5	304	32	74,5	10371,5
5	336	32	80,1	11134,4
8	352	32	82,7	11769

Table 1: Determined characteristics of the jet geometry for varied spray pressures and nozzle distances (a) a = 100 mm; (b) b = 200 mm

Results and discussions

Influence of nozzle size under practically oriented spraying conditions

The droplet spectra, formed through the variation of the examined quantities of the operational parameters, show relatively little differences within volume distributions of the droplets and the mean volumetric diameters respectively, referring to an optimal spray effect. The droplet distributions of the agricultural nozzle LU 90-04 show definitely more smaller droplets (30 ... 48% of total volume). This has a negative influence on the spray effect. In contrast to the agricultural nozzle LU 90-04 (spray bore (0,75 mm), the use of the industrial nozzle 632.726 (spray bore (1,7 mm) involves a decrease of the volume of droplets < 0,25 mm by 22 up to 34%, depending on the spray pressure (3 < p < 8 bar) and the examined nozzle distances.

In the case of the industrial nozzle, this also results in a clear increase of the number of droplets > 0,25 mm as well as of the mean velocity for droplets or classes of droplets having the same size.

The agricultural nozzle LU 90-04 is characterised by a low volume flow rate and

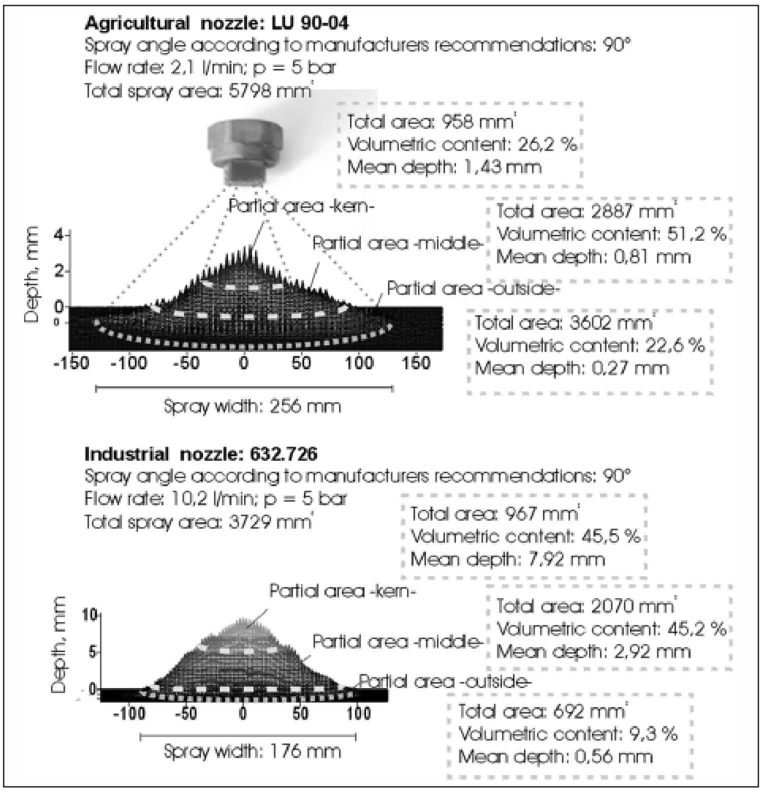

Fig. 1: Results of measuring the material removal and partial area related data on mean depth of material removal and volumetric spray water content at 100 mm distance

large jet angle, which produce a jet with a large radial jet dispersion and thus a low droplet concentration. The characteristics of the larger spray hole cross section of the nozzle 632.726, to increase the droplet diameter, is caused by the increased flow rate of the nozzle.

A calculation of the mean droplet impulse from the measured values of the droplet mass and velocity reveals a significant difference of the nozzles concerning the mean impulse values of droplets per unit spraying area under the same spray pressure. All droplet size classes of the industrial nozzle 632.726 show a higher mean value. The increase of the mean droplet impulse with the industrial nozzle 632.726 causes a faster impact of droplets on the surface with lower radial driftage (*Tab. 1*).

This higher density of the droplet stream (DSD) and the volume stream (VSD), associated with an optimal droplet impulse, led to the increasing jet effect on the spraying area. The measurements via the pressure sensor show that due to the increase of the velocity and therefore the drop impulse, an increase in the mean maximum impact force within the jet spray area is achieved (*Fig. 1, Table 2*).

The effectiveness of the spray structure of two nozzles is expressed through the applied energy per volume of material removal on the standard sand-binder mixture plate (specific hydraulic energy, Nm/mm^2) and through the extend of the nozzle-specific drop in pressure resulting from the geometrical dimension of the nozzle, which causes certain flow conditions and force effects on the flow particles (quotient from the maximal impact pressure and the water pressure within the supply line in front of the nozzle, p_1/p_0). According to that, the data of the spray structure of the agricultural nozzle LU 90-04 proved to be rather ineffective, especially concerning its use with a nozzle distance > 10 cm. The lacking effectiveness becomes further apparent through higher energy values per volume of material removal.

nozzle distance (mm)	density of volume stream (mm^3/mm^2 s)	total calculated impulse (kg m/s)	mean droplet impulse (kg m/s)
Agricultural nozzle LU 90-04			
100	6,04	0,723	$6{,}6 \cdot 10^{-7}$
200	1,62	0,720	$4{,}9 \cdot 10^{-7}$
Industrial nozzle 632.726			
100	31,80	3,67	$3{,}0 \cdot 10^{-6}$
200	6,58	3,94	$2{,}1 \cdot 10^{-6}$

nozzle distance (mm)	mean maximum impact pressure (kPa)	mean depth of material removal (mm)	$E_{hyd.,spez.}$ used energy / volume removed (N m / mm^3)	pressure ratio p_1/p_0 (-)
Agricultural nozzle LU 90-04				
100	11,14	0,63	1,12	$2{,}23 \cdot 10^{-2}$
200	10,92	0,30	4,09	$2{,}18 \cdot 10^{-2}$
Industrial nozzle 632.726				
100	28,63	2,47	1,41	$5{,}73 \cdot 10^{-2}$
200	24,57	1,05	1,80	$4{,}91 \cdot 10^{-2}$

Table 2: Comparing determined nozzles spraying parameters, dependent on two selected nozzle distances, p = 5 bar

The results show that the distribution of the density of the volume flow, the mean droplet impulse within the spray jet and the total impulse of the spray jet inform about the surface performance of the jet (impulse- and impact force effect). The named parameters are connected to each other, and their respective value influences the spray effectiveness of the nozzle. Thus, the nozzle size has a significant influence on the liquid volume- and impulse demand, necessary for the cleaning effectiveness.

Conclusions

The developed testing method offers the possibility of analysing washing nozzles concerning their effect-relevant jet parameters depending on varying operating and nozzle parameters. The results of analysis show that primarily the nozzle size considerably affects the conditions for the formation of the spray jet structures and thus the jet effect as well as effectiveness. A nozzle with a low flow rate (Q < 3 l/min at p = 3 bar) and a large jet angle (a ≥ 90°) produces a spray jet which is characterised by a reduced droplet density as well as volume flux plus an increased air ratio within the spray jet and accordingly by a strong impulse-minimising air influence on the droplets of the spray jet. Considering the water saving potential and gentle vegetable cleaning, these values of jet structure can be improved by increasing the nozzle size.

The experiments with different washing nozzles allow clues about the energetically effective size range of the droplet spectrum. The result of a parameter determination of optimally effective droplet size spectra in the spray jet is presented in *figure 2*.

Further viewing of the droplet spectra shows an increased frequency of large droplets with higher impulse values. This tendency, particularly at a nozzle distance of 10 cm, can be considered as damaging due to the higher impact pressure effect. To what extent this statement is to be justified from the view of gentle vegetable cleaning, will be shown by the interpretation of the test results for determination of the damage limit of different vegetable types.

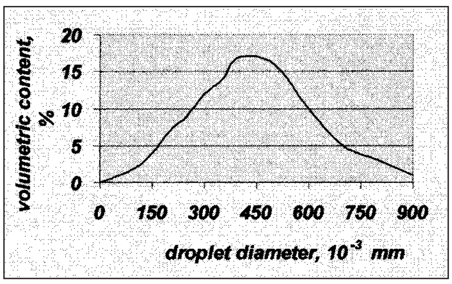

Fig. 2: Energetically optimal and effect relevant droplet size spectrum of spray jet