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Proportion of workers having work-related asthma symptoms in a cassava factory, Nakhon Ratchasima province, Thailand

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Abstract

Flour dust is one of work-related asthma (WRA) allergens. Few researches have been done on WRA symptoms in workers exposed to cassava starch. The aim of this study was to determine the proportion of WRA symptoms and definite WRA in a cassava factory. We conducted a descriptive study in which a sample of 148 employees was identified at a cassava factory in Nakhon Ratchasima. All had worked 6 months or longer. The study included: 1) screening for asthma-like symptoms using a modified ECRHS questionnaire; 2) screening for WRA symptoms using a questionnaire and physical examination by an occupational medicine doctor; and, 3) diagnosis confirmation using serial peak expiratory flow interpreted by OASYS-2 software. Descriptive statistics were used to assess the findings. The response rate was 87.2% (129/148) -males comprised 72.1% (93/129) of the sample. The proportion of asthma-like symptoms was 58.1% (75/129). Among 129, WRA symptoms was 11.6% (95%CI: 6.6, 17.3) and definite WRA was 3.1% (95%CI: 0.7, 6.5). In the 15 cases of WRA symptoms, 60% had a job task with high exposure to cassava starch. In cases of respiratory symptoms, most (86.7%) had upper respiratory symptoms and all had lower respiratory symptoms. Cough and dyspnea were the most common lower respiratory symptoms (each was 60%) followed by chest tightness (53.3%) and wheezing (26.7%). WRA symptoms and definite WRA constituted 11.6% and 3.1% in a cassava starch factory, respectively. The results showed a consistence with previous studies in developing nations. Cassava starch, like wheat flour, may cause WRA.

Keywords: Work-related asthma, Occupational asthma, Cassava, Tapioca, Starch

1. Introduction

Work-related asthma (WRA) occurred in between 10 and 25 % of all adults with asthma [1-3]. There are currently more than 400 types of known asthmagens, one of the top three being flour dust [1, 4]. Previous studies have demonstrated that the proportion of WRA and WRA symptoms in workers exposed to flour dust was between 3.0 and 5.5 % in western countries [5,6] and 2 and 56% in developing nations [7,8]. There has not, however, been a study of cassava starch, which would be more prevalent in Thailand because it is a major crop. In the cassava starch production process, particles between 2 and 35 μm are found; particles small than 5 μm can pass into the lower respiratory tract. Cassava starch contains small proteins and is moderately acidic (pH 3-5). These properties cause inflammation of the respiratory system, leading to asthma [9-11]. In 2018, there was a report of WRA confirmed by occupational exposure to cassava starch [12].

In the current descriptive study, a group of cassava factory workers underwent a step-wise investigation. The questionnaire was completed by interviewing participants. Positive WRA-symptom participants had their

diagnosis confirmed using serial peak expiratory flow (PEF) as interpreted by OASYS-2 [18,19,21]. This approach permitted researchers to study the proportion of WRA symptoms in the cassava factory. Asthma can be prevented by removal of the identifiable factors, before airway remodeling [13-15]. There has, however, been a few researches on WRA in workers exposed to cassava starch. Perhaps by estimating the size of the problem, prevention strategies and monitoring the health effects among employees can be planned. The study was undertaken in Nakhon Ratchasima province where there are the highest concentration of cassava starch factories and exposed employees in Thailand.

2. Materials and methods

2.1 Study design

A descriptive study was applied.

2.2 Study population and sample

The study population included workers from a medium-sized cassava starch factory located in Nakhon Ratchasima, northeast Thailand. This cassava factory uses standard production processes and has relatively poor environmental controls. As a consequence, the selected factory may have many workers excessively exposed to cassava starch and suffering from WRA; it is therefore a representative factory for study.

The study population included persons (a) being 18 or over, and (b) have been working in the factory for 6 or more months. The exclusion criteria were (a) any contraindications for lung function testing with a peak flow meter (b) inability to communicate in Thai (c) any underlying diseases affecting lung function (i.e., active pulmonary tuberculosis, emphysema, chronic bronchitis, or morbid obesity). Each worker was invited to join the three-step study. The study population comprised 148 workers. The response rate was 87.2% (129/148) in Step 1, 76.0% (57/75) in Step 2, and 100% (15/15) in Step 3 (Figure 1).

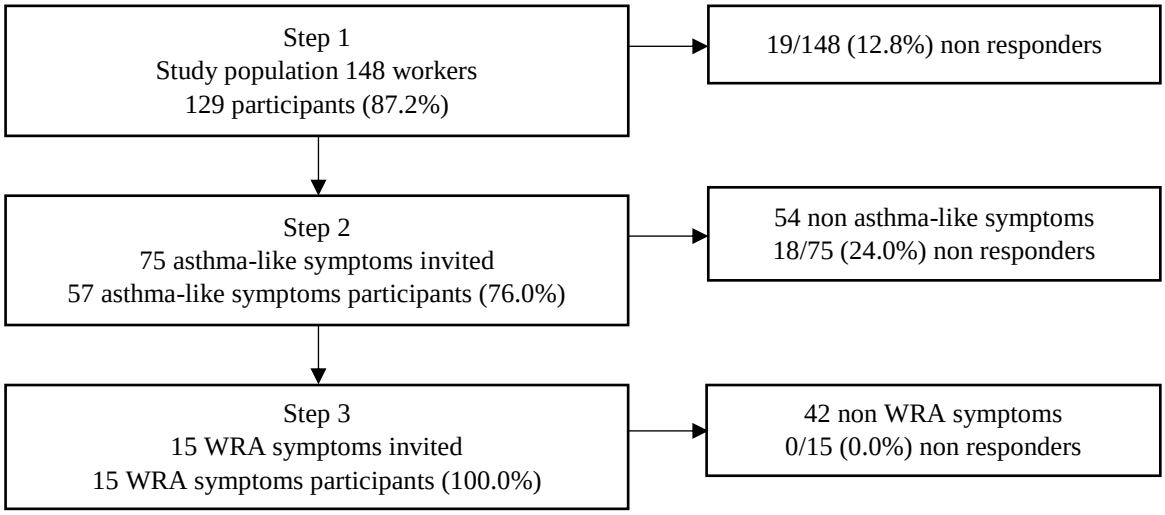

Figure 1 Participants' responses.

2.3 Characteristics of workplace

The factory processes cassava from locally-grown starch. Production occurs for 8 to 10 months a year. The factory achieves 24-h production by having employees work five to six days per week, in three shifts of 8 h/d. The morning shift runs between 0800 and 1600, the afternoon between 1600 and 2400, and the night between 2400 and 0800. Workers change shifts weekly. The production process is divided into two departments: (1) *Production*, which includes pre-production, production, packing, and storage; and (2) *Production Support*, which includes office, transportation, maintenance, cleaning, and engineering. The *Production Department* is under one roof in which natural and mechanical ventilation are used and the quality of air at the time of sampling was quite low. Cassava starch dust was extensively airborne, especially in the *Packing and Storage Section*. Most workers used clothe masks and some did not use any respiratory protective equipment at all.

2.4 Tools

2.4.1 Questionnaire

Two questionnaires were used-one in Step 1 and one in Step 2 of the study. Asthma-like symptoms were screened in the Step 1 questionnaire. These questionnaires were modified from the ECHRS questionnaire [16] by forward and backward translation into Thai and pre-tested in 60 workers at a cassava starch factory in Kalasin province, northeast Thailand. The Cronbach's Alpha for the asthma-like symptoms screening questionnaire was 0.85. The self-administered questionnaire comprised three parts: (a) general personal information, (b) job information, and (c) abnormal respiratory symptoms. The WRA symptoms screening interview questionnaire was used in Step 2. The questionnaire was modified from Chaiear et al. [13,17] and comprised six parts: (a) general personal information, (b) smoking history, (c) health information, (d) job information, (e) abnormal respiratory symptoms, and (f) contraindication(s) to the serial PEF test. The interviewers were performed by two occupational medicine physicians and eight occupational medicine residents trained in a short course on occupational medicine. The questionnaire was completed by trained interviewers.

2.4.2 Serial peak expiratory flow

The WRA symptoms subjects were invited to confirm diagnosis by serial PEF. The researcher trained each subject how to use the peak flow meter and record the data. The subjects were asked to measure the best of three blows each time. If the highest two readings differed by more than 20 l/min, then more readings were required. The minimum criterion required for a record to be included was that the PEF reading for four weeks over two work and two rest periods, at least four readings per day (viz., upon waking; at start of work or 1-2 h after starting work; upon finishing work; and, before bed) [18-20].

2.4.3 OASYS-2

The OASYS-2 was used to interpret the results of serial PEF. The criteria for diagnosing WRA must be at least one of the following: 1) an OASYS score > 2.5; 2) the area between the curve score (ABC scores) ≥15 l/min/h; and, 3) the time point analysis being positive [18,19,21].

2.5 Data collection

The study was carried out in 3 steps. Step 1-all participants were screened for asthma-like symptoms using a self-administered questionnaire; Step 2-participants with asthma-like symptoms from Step 1 were screened for WRA symptoms by a questionnaire interview conducted by occupational medicine doctors; and, Step 3-participants with WRA symptoms from Step 2 had their diagnosis confirmed over the course of 3 to 4 weeks by serial PEF interpreted by OASYS-2. The criteria for diagnosing WRA symptoms and its subgroups depended upon the WRA screening questionnaire and OASYS-2 (Table 1).

Table 1 Criteria for diagnosing WRA symptoms and establishing subgroups.

Step	WRA symptoms		
	Definite WRA	Probable	Possible
Step 1-asthma-like symptoms screening	Positive	Positive	Positive
Step 2-4 questions WRA symptoms screening Item 1 lower respiratory symptoms better when away from work Item 2 lower respiratory symptoms worst at work Item 3 having asthmagens in working process Item 4 exposed to asthmagens in working process	Positive ≥1 item which must have first and / or second item	Positive all item	Positive 1-3 item which must have first and / or second item
Step 3-serial PEF with OASYS-2	Positive	Negative or cannot evaluate	Negative or cannot evaluate

2.6 Data analysis

Descriptive statistics were applied and the results presented as frequencies, percentages, and p-values. All analyses were performed using SPSS (version 19.0, IBM SPSS Inc, Chicago, IL). The study was reviewed and approved by the Khon Kaen University Ethics Committee for Human Research (HE 611435).

3. Results

The number of cases studied was 129. Males constituted the majority of participants (72.1%). The median age of all participants was 40 (IQR 22 to 54). Most of the participants in Steps 2 and 3 do not smoke (54.4 and 66.7, respectively). Some 10.9% (14/129) of participants had an underlying disease and this was most commonly hypertension (35.7%) or diabetes mellitus (21.4%). History of atopy and family history of atopy were slightly increased in participants at Steps 2 and 3 (49.1% and 36.8%; 73.3% and 46.7%, respectively) (Table 2).

Table 2 General characteristics of participants.

General characteristics	Step 1 (n=129)		Step 2 (n=57)		Step 3 (n=15)	
	n	%	n	%	n	%
Sex						
Male	93	72.1	34	59.6	7	46.5
Female	36	27.9	23	40.4	8	53.3
Smoking habits						
Never smoked	N/A		31	54.4	10	66.7
Current smoker	N/A		12	21.1	3	20.0
Ex-smoker	N/A		14	24.6	2	13.3
Underlying diseases	14	10.9	11	19.3	6	40.0
Hypertension	5	35.7	3	27.3	2	33.3
Diabetes mellitus	3	21.4	2	18.2	1	16.7
Thyroid diseases	3	21.4	3	27.3	0	0.0
Atopy	2	14.3	2	18.2	2	33.3
Asthma	2	14.3	2	18.2	2	33.3
Others	2	14.3	2	18.2	0	0.0
History of atopy	N/A		28	49.1	11	73.3
Family history of atopy	N/A		21	36.8	7	46.7
Median age (interquartile range)	40 (22 to 54)		41 (25 to 54)		41 (26 to 52)	

Most job tasks category resulted in high cassava starch exposure at all Steps (65.1%, 66.7%, and 60.0%, respectively). Most (42.2%) of the low cassava starch exposure occurred in workers doing documentation and computer work. The highest cassava starch exposure occurred in workers doing the bagging of cassava starch (15.5%) (Table 3).

Table 3 Job task of participants.

Job task	Step 1 (n=129)		Step 2 (n=57)		Step 3 (n=15)	
	n	%	n	%	n	%
Low exposure to cassava starch	45	34.9	19	33.3	6	40.0
Documentation using a computer	19	42.2	7	36.8	3	50.0
Drive crane to scoop cassava roots	5	11.1	3	15.8	1	16.7
Cleaning and screening cassava roots	5	11.1	4	21.1	1	16.7
Engine repair (trucks, forklifts, cars)	4	8.9	2	10.5	0	0.0
Maintenance of electrical systems of cars and offices	3	6.7	0	0.0	0	0.0
Care and design of machinery	2	4.4	0	0.0	0	0.0
Weigh and measure percentage of cassava roots	2	4.4	1	5.3	1	16.7
Chopped and crushed cassava roots	1	2.2	1	5.3	0	0.0
Cleaning the office and the road in the factory	1	2.2	0	0.0	0	0.0
Planting trees, watering trees, pruning branches	1	2.2	0	0.0	0	0.0
Dump cassava roots from crane	1	2.2	0	0.0	0	0.0
Drive the cassava starch truck	1	2.2	1	5.3	0	0.0

Job task	Step 1 (n=129)		Step 2 (n=57)		Step 3 (n=15)	
	n	%	n	%	n	%
High exposure to cassava starch	84	65.1	38	66.7	9	60.0
Control release of cassava starch into bags	13	15.5	5	13.2	0	0.0
Control boiler machine	11	13.1	0	0.0	0	0.0
Repairing machinery in production process	10	11.9	5	13.2	1	11.1
Check quality of cassava starch	9	10.7	5	13.2	2	22.2
Document work and walk in production process	9	10.7	7	18.4	1	11.1
Production line leader and assistant	8	9.5	5	13.2	2	22.2
Drive forklift to move cassava flour bags	6	7.1	2	5.3	0	0.0
Check stock, control import and export of goods	6	7.1	6	15.8	2	22.2
Turbo control (Adjusting quality of flour water)	4	4.8	1	2.6	0	0.0
Control cassava waste separation machine	3	3.6	1	2.6	0	0.0
Control cyclone machine	3	3.6	0	0.0	0	0.0
Cleaning machinery in production process	1	1.2	1	2.6	1	11.1
Control and care electrical systems in production line	1	1.2	0	0.0	0	0.0
Other job exposure to asthmagens	N/A		2	3.5	0	0.0

Most of the participants at Steps 2 and 3 sensed 'having' asthmagens in the working process (82.5% and 73.3%, respectively), which matched 'perceiving' exposure to asthmagens in the working process (70.2% and 60.0%, respectively). Cassava starch was the most common asthmagen (~70% in Step 2 vs. 80% in Step 3). The median years of employment was quite similar among persons in each Step: Step 1-11.3 years (IQR 1.1 to 21.1); Step 2-12.2 years (IQR 1.1 to 21.2); and, Step 3-13.3 years (IQR 3.8 to 19.4). The median years of exposure to asthmagens in Step 2 was 4.3 years (IQR 0 to 21.2), which was virtually the same in Step 3 at 4.2 years (IQR 0 to 19.4) (Table 4). All the WRA symptoms participants in Step 3 used inappropriate respiratory protective equipment (Table 5).

Table 4 Job characteristics of participants.

Job characteristic	Step 1 (n=129)		Step 2 (n=57)		Step 3 (n=15)	
	n	%	n	%	n	%
Low exposure to cassava starch	45	34.9	19	33.3	6	40.0
High exposure to cassava starch	84	65.1	38	66.7	9	60.0
Having asthmagens in working process	N/A		47	82.5	11	73.3
Cassava starch dust	N/A		32	68.1	9	81.8
Sulfuric acid	N/A		11	23.4	5	45.5
Sodium metabisulfite	N/A		9	19.1	4	36.4
Hydrogen peroxide	N/A		6	12.8	2	18.2
Others	N/A		18	38.3	4	36.4
Exposed to asthmagens in working process	N/A		40	70.2	9	60.0
Cassava starch dust	N/A		26	65.0	7	77.8
Sodium metabisulfite	N/A		7	17.5	3	33.3
Sulfuric acid	N/A		6	15.0	3	33.3
Hydrogen peroxide	N/A		5	12.5	2	22.2
Others	N/A		15	37.5	3	33.3
Median years of employment (IQR)	11.3 (1.1 to 21.2)		12.2 (1.1 to 21.2)		13.3 (3.8 to 19.4)	
Median years of exposure (IQR)	N/A		4.3 (0.1 to 21.2)		4.2 (0.1 to 19.4)	

Table 5 Respiratory protective equipment of participants.

Respiratory protective equipment (RPE)		Step 1 (n=129)		Step 2 (n=57)		Step 3 (n=15)	
		n	%	n	%	n	%
Use RPE	Not proper	N/A		55	96.5	15	100.0
	Proper	N/A		2	3.5	0	0.0

The proportion of asthma-like symptoms was 58.1% (75/129), 95%CI: 50.0, 66.4. The proportion of WRA symptoms was 11.6% (15/129): including, definite WRA 26.7% (4/15), probable WRA 26.7% (4/15), and possible WRA 46.7% (7/15). The proportion of definite asthma was 3.9% (5/129): including, definite WRA 40% (2/5), probable WRA 20% (1/5), and possible WRA 40% (2/5) (Table 6).

Table 6 Diagnosis of participants.

Diagnosis	Total (n=129)	95%CI	Cassava starch exposed		Years of exposure	
			High (n=84)	Low (n=45)	<5 (n=30)	≥5 (n=27)
Asthma-like symptoms	75 (58.1)	50.0-66.4	52 (61.9)	23 (51.1)	30 (100.0)	27 (100.0)
WRA symptoms	15 (11.6)	6.6-17.3	9 (10.7)	6 (13.3)	8 (26.7)	7 (25.9)
definite WRA	4 (3.1)	0.7-6.5	3 (3.6)	1 (2.2)	3 (10.0)	1 (3.7)
probable WRA	4 (3.1)	0.7-6.4	4 (4.8)	0 (0.0)	0 (0.0)	4 (14.8)
possible WRA	7 (5.4)	1.6-10.0	2 (2.4)	5 (11.1)	5 (16.7)	2 (7.4)
Definite asthma	5 (3.9)	0.8-7.6	3 (3.6)	2 (4.4)	2 (6.7)	3 (11.1)
definite WRA	2 (1.6)	0.0-4.1	2 (2.4)	0 (0.0)	1 (3.3)	1 (3.7)
probable WRA	1 (0.8)	0.0-2.5	1 (1.2)	0 (0.0)	0 (0.0)	1 (3.7)
possible WRA	2 (1.6)	0.0-4.3	0 (0.0)	2 (4.4)	1 (3.3)	1 (3.7)
Non-WRA	0 (0.0)	N/A	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

Fifty-seven asthma-like symptoms participants in Step 2 had upper respiratory symptoms (61.4%) more frequently than lower respiratory symptoms (26.3%), but in Step 3 15 participants with WRA symptoms had lower respiratory symptoms (100.0%) more frequently than upper respiratory symptoms (86.7%). Eye/nose irritation was the most common upper respiratory symptoms (76.9%). Cough (60.0%) and dyspnea (or shortness of breath) (60.0%) occurred most commonly in lower respiratory symptoms (Table 7).

Table 7 Respiratory symptoms of participants.

Respiratory symptom	Step 2 (n=57)		Step 3 (n=15)	
	n	%	n	%
Abnormal upper respiratory symptoms	35	61.4	13	86.7
Eye/nose irritation	23	65.7	10	76.9
Throat irritation	15	42.9	9	69.2
Nasal congestion, Rhinorrhea	13	37.1	5	38.5
Abnormal lower respiratory symptoms	15	26.3	15	100.0
Cough	9	60.0	9	60.0
Dyspnea or shortness of breath	9	60.0	9	60.0
Chest tightness	8	53.3	8	53.3
Wheezing	4	26.7	4	26.7

The male to female proportion of the 15 participants who had WRA symptoms was 46.7% to 53.3%. The proportion of high cassava starch exposure participants to low exposure was similar (46.7% to 53.3%). The median years of employment was 13.3 years (IQR 3.8 to 19.4) and the median years of exposure was 4.2 years (IQR 0 to 19.4). Thirteen of 15 participants had an acceptable quality of PEF record and 1 of the 4 definite WRA participants had an OASYS score > 2.5 (Table 8).

Table 8 General and job characteristics of definite WRA participants.

NO	Sex	Cassava starch exposure	Years of employment	Years of exposure	Quality of PEF record	OASYS score	ABC score	Time point analysis
1	F	High	13.3	13.3	Acceptable	2	3.5	positive
2	F	High	4.2	4.2	Acceptable	2.1	51.9	negative
3	F	High	8.5	1.5	Acceptable	3.4	3.3	negative
4	M	Low	5.5	0	Acceptable	2.4	16.5	positive

4. Discussion

The proportion of asthma-like symptoms was 58.1% (75/129), 95%CI: 50.0, 66.4. Seventy-six percent of the asthma-like symptoms participants (57/75) responded to Step 2 of the study. They had upper respiratory symptoms (61.4%) more frequently than lower respiratory symptoms (26.3%). Consistent with previous studies, it was found that 51.9% of the employees exposed to wheat flour dust had upper respiratory symptoms [8]. The proportion of definite asthma was 3.9% (5/129), which is consistent with the general population (2.9-5.0%) [5,22], but perhaps

lower than expected as the study population was more exposed to asthmagens than the general population, especially to cassava starch dust. Five of the participants had definite asthma-including, definite WRA 40.0% (2/5), possible WRA 20.0% (1/5), and probable WRA 40.0% (2/5). Previous studies have found that WRA ranged between 10 and 25% among asthmatic adults, which is lower than the current study [1-3].

Results of the current study revealed that the proportion of WRA symptoms was 11.6% (15/129), 95%CI: 6.6-17.3, including definite WRA 3.1% (4/129), possible WRA 3.1% (4/129), and probable WRA 5.4% (7/129). Previous studies have shown that most of the less developed countries have a greater prevalence of WRA or WRA symptoms in workers exposed to flour dust than the developed West where there are stricter health and safety standards requiring appropriate PPE (i.e., between 2.0-56.0% in less developed African and Middle Eastern countries [7,8] vs. 3.0-5.5% in more developed western European countries [5,6]). The climate, moreover, of tropical, southern countries is hotter and more humid than European countries, hastening the growth of microorganism which cause asthma [23].

The proportion of WRA symptoms was fewer than might have been expected as 89 workers quit their job before the end of the study due contract termination. The "healthy worker effect" may be the reason why the proportion was relatively low. A previous study research revealed that bakery workers with asthma symptoms had to change or quit their jobs (self-selection) [6,26]. In our study, a step-wise approach was used for data collection, as was done by Talini et al. [6]. Both studies encountered the problem of participants who did not participate in each step; perhaps explaining why the proportion of WRA symptoms was underestimated.

Oh et al. in Korea studied the prevalence of WRA-based on data from the Korea Workers' Compensation and Welfare Service (COMWEL)-and found only 1.3% of WRA due to flour dust exposure [30]. Both workers and the doctors making the diagnosis lacked information about asthmagens; but the authors concern more on doctors' lack of knowledge on work processes and workers' risk. This resulted in lack of awareness and incorrect information about respiratory symptoms, delayed diagnosis and treatment [27-29].

Most of the participants have asthmagens and were exposed to asthmagens in their work process (82.5% and 70.2%, respectively). Nearly 70% of participants experienced exposure to airborne cassava starch. The proportion of WRA symptoms in participants with high exposed to cassava starch was 10.7% (9/84), which is slightly lower than the low exposure group (13.3%). The difference may be because workers did not have information about asthmagens, resulting in a lack of awareness and incorrect information about respiratory symptoms. But the proportion of definite asthma in workers with high exposure was noticeably higher than those with low exposure (3.6% and 2.2%, respectively and p-value = 0.57). Cassava starch might contain important asthmagens as indicated by the current study. Previous studies found flour mill and/or bakery workers exposed to flour dust were associated with respiratory symptoms disorders, reduction of lung function, and the occurrence of WRA [6,7,23, 25,26]. Three of four definite WRA were highly exposed to cassava starch and their duration of exposure was less than 5 years. Consistent with the study by Smith et al., 51% of wheat flour dust exposed workers experience respiratory irritation and 42% have occupational asthma in the first 5 years [5]. Some studies show fungal amylase enzyme in flour dust as the cause of WRA in bakery workers, but cassava starch does not have fungal amylase enzyme [5,24]. Cassava starch has a small granule size (less than 5 μm) and contains some proteins and is moderately acidic (pH 3-5); these properties are close to flour dust [9-11]. Such particles can pass though the lower respiratory tract and stimulate Ig-E (type1 hypersensitivity), causing inflammation of the bronchi and leading to asthma after about 6 months to 2 years [12,15]. In addition, the physical properties of cassava starch irritate the respiratory system, leading to asthma [12]. In 2018, a WRA patient report confirmed work exposure to cassava starch [12]. Cassava starch may therefore cause asthma albeit few studies have been done in Thailand or elsewhere.

This is the first descriptive study to reveal the proportion of work-related asthma (WRA) symptoms among cassava factory workers in Thailand. Cassava starch may therefore be the cause of asthma among workers exposed to cassava starch. Early diagnosis and known asthmagens can help to avoid contact and airway remodeling [13-15].

5. Conclusion

WRA symptoms and definite WRA constituted 11.6% and 3.1% in a cassava starch factory, respectively. The results showed consistent with previous studies in developing nations. Cassava starch, like wheat flour, may cause WRA.

6. Acknowledgements

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7. References

[1] Blanc PD, Toren K. How much adult asthma can be attributed to occupational factors? Am J Med. 1999;107(6):580-587.

[2] Jeebhay MF. Work-related asthma. Contin Med Educ 2009;27(11):496-501.

[3] Torén K, Blanc PD. Asthma caused by occupational exposures is common-a systematic analysis of estimates of the population-attributable fraction. BMC Pulm Med [Internet] 2009 [cited 2019 Sep 15]. Available from: https://bit.ly/2Rb7Hp9

[4] Vandenplas O. Occupational asthma: etiologies and risk factors. Allergy Asthma Immunol Res. 2011;3(3):157-167.

[5] Smith TA, Lumley KP. Work-related asthma in a population exposed to grain, flour and other ingredient dusts. Occup Med Oxf Engl. 1996;46(1):37-40.

[6] Talini D, Benvenuti A, Carrara M, Vaghetti E, Martin LB, Paggiaro PL. Diagnosis of flour-induced occupational asthma in a cross-sectional study. Respir Med. 2002;96(4):236-243.

[7] Ijadunola KT, Erhabor GE, Onayade AA, Ijadunola MY, Fatusi AO, Asuzu MC. Prevalence of respiratory symptoms among wheat flour mill workers in Ibadan, Nigeria. Am J Ind Med. 2004;45(3):251-259.

[8] Ajeel NA, Al-Yassen AK. Work-related allergic disorders among flour mill workers. Med J Basrah Univ. 2007;25(1):29-32.

[9] Zhu F. Composition, structure, physicochemical properties, and modifications of cassava starch. Carbohydr Polym. 2015;122:456-480.

[10] Molenda M, Stasiak M, Horabik J, Fornal J, Blaszczak W, Ornowski A. Microstructure and mechanical parameters of five types of starch. Pol J Food Nutr Sci. 2006;56(2):161-168.

[11] Koh SP, Long K. Comparison of physical, chemical and functional properties of broken rice and breadfruit starches against cassava starch. J Trop Agric Food Sci. 2012;40(2):211-219.

[12] Wiggans R, Pilling J, Hoyle J. Tapioca starch powder as a new cause of occupational asthma in bakers. Eur Respir J. 2018;52(Suppl 62):PA4529.

[13] Chaiear N, Jongkumchok W, Boonsawat W, Chaisuksant S. Work-related asthma amongst asthmatic patients in the easy asthma clinics in Khon Kaen, Thailand. Occup Environ Med. 2018;75(Suppl 2):A460-461.

[14] Cullinan P, Taylor AN. Occupational asthma. In: Baxter P, Hunter D, editors. Hunter's diseases of occupations. 10th ed. London: Hodder Arnold; 2010. p. 941-957.

[15] Balmes JR. Occupational lung diseases. In: LaDou J, editor. Current occupational and environmental medicine. 5th ed. New York: McGraw-Hill Medical; 2014. p. 362-385.

[16] Grassi M, Rezzani C, Biino G, Marinoni A. Asthma-like symptoms assessment through ECRHS screening questionnaire scoring. J Clin Epidemiol. 2003;56(3):238-247.

[17] Chaiear N, Sadhra S, Jones M, Cullinan P, Foulds IS, Burge PS. Sensitisation to natural rubber latex: an epidemiological study of workers exposed during tapping and glove manufacture in Thailand. Occup Environ Med. 2001;58(6):386-391.

[18] Jares EJ, Baena-Cagnani CE, Gómez RM. Diagnosis of occupational asthma: an update. Curr Allergy Asthma Rep. 2012;12(3):221-231.

[19] Burge PS, Moore VC, Burge CBSG, Vellore AD, Robertson AS, Robertson W. Can serial PEF measurements separate occupational asthma from allergic alveolitis? Occup Med Oxf Engl. 2015;65(3):251-255.

[20] National Asthma Education and Prevention Program. How to use a peak flow meter [Internet]. 2013 [cited 2019 Oct 5]. Available from: https://bit.ly/34Ji8ob

[21] Gannon PF, Newton DT, Belcher J, Pantin CF, Burge PS. Development of OASYS-2: a system for the analysis of serial measurement of peak expiratory flow in workers with suspected occupational asthma. Thorax. 1996;51(5):484-489.

[22] Dejsomritrutai W, Nana A, Chierakul N, Tscheikuna J, Sompradeekul S, Ruttanaumpawan P, et al. Prevalence of bronchial hyperresponsiveness and asthma in the adult population in Thailand. Chest. 2006;129(3):602-609.

[23] El Gewily MS, El Husseini M, Beshir S, Elserougy S, Hafez SF, El Hamshary MS. Diagnosis of occupational asthma in flour mills at South Cairo. Egypt J Community Med. 2018;36(1):95-103.

[24] Malo J-L, Chan-Yeung M. Agents causing occupational asthma. J Allergy Clin Immunol. 2009;123(3):545-550.

[25] Meo SA. Dose responses of years of exposure on lung functions in flour mill workers. J Occup Health. 2004;46(3):187-191.

[26] Prichard MG, Ryan G, Musk AW. Wheat flour sensitisation and airways disease in urban bakers. Occup Environ Med. 1984;41(4):450-454.

[27] Walters GI, Soundy A, Robertson AS, Burge PS, Ayres JG. Understanding health beliefs and behavior in workers with suspected occupational asthma. Respir Med. 2015;109(3):379-388.

[28] Poonai N, van Diepen S, Bharatha A, Manduch M, Deklaj T, Tarlo SM. Barriers to diagnosis of occupational asthma in Ontario. Can J Public Health. 2005;96(3):230-233.
[29] Bradshaw LM, Barber CM, Davies J, Curran AD, Fishwick D. Work-related asthma symptoms and attitudes to the workplace. Occup Med Oxf Engl. 2007;57(1):30-35.
[30] Oh SS, Kim KS. Occupational asthma in Korea. J Korean Med Sci. 2010;25(Suppl):S20-25.