Development of a black galingale dryer using biomass working together with a CLOHP/CV heat exchanger

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Abstract

This research was designed to test a black galingale dryer working together with a CLOHP/CV heat exchanger. The dimensions of the drying chamber were 0.6´1.0´1.0 m. The heat exchanger in this study was a closed-loop oscillating heat pipe with check valves (CLOHP/CV) using ethanol and water as the working fluids with a filling ratio of 50% (by total volume of tube). The CLOHP/CV was made of a copper tube with an inner diameter of 2.03 mm. The evaporator, adiabatic and condenser lengths were equal to 200, 100 and 200 mm. The number of turns was 50. The experimental results showed that the moisture content of the black galingale decreased from 143 % (wb) to 2.88% (wb). In addition, the type of working fluid affected the drying time. It was found that the fuel quantity, drying time, heat transfer rate and effectiveness of using ethanol and water as the working fluids were (13.5 kg and 25 kg), (6.30 hr and 10.30 hr), (1851.93 watt and 1078.71 watt) and (0.48 and 0.31) respectively, In conclusion, development of a black galingale dryer using by biomass working together with a heat exchanger was found to be technically suitable for drying black galingale and could reduce energy costs.

Keywords: Closed-loop oscillating heat pipe (CLOHP), check valve (CV), heat exchanger, drying, biomass.

Introduction

Black galingale is a Thai herb used to cure diseases such as dysentery, heart trouble, and diabetes. Black galingale can also cure aches and pains and helps in discharging urine. Moreover, black galingale is a carminative and increases sexual performance. The parts of the black galingale that are used include the leaves, roots and trunk[1]. Due to its curative abilities, it would be advantageous to keep black galingale for long periods of time so it could be used anytime.

Drying is a dehumidification process of a product using heat transfer. Drying can maintain a product for a long time, which ultimately increases its value. The normal energy used for drying is electrical energy, oil and fuel gas. These energy types are wasteful and expensive. Recently, biomass was used as the energy in a drying process. J. Prasad and V.K. Vijay[2] studied a solar-biomass hybrid drier for use with Zingiberofficinale, Curcuma longa l. and Tinosporacordifolia as experimental products. It was found that an initial moisture content of 319.74 %db for their fresh product was dried to a final moisture content of 11.8 %db within 33 hrs. The time for drying with a solar dryer was decreased from 72 - 120 hrs. to 33 - 48 hrs when a solar-biomass hybrid drier was used. M. Mohanrajand P. Chandrasekar[3] studied the drying of copra in a forced convection solar drier. It was found that drying copra in the drier reduced its moisture content from about 51.8% to 7.8% and 9.7% in 82h for

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trays located at the bottom and top of the drier, respectively. M.A. Hossain and B.K. Bala[4] studied the drying of hot chili using a solar tunnel drier. It was found that the moisture content of the red chili was reduced from 2.85 to 0.05 kgH_2O kg^{-1} (db) in 20 h in a solar tunnel drier, and it took 32 h to reduce the moisture content to 0.09 and 0.40 kgH2Okg^{-1}(db) in improved and conventional sun drying methods, respectively.

A heat pipe is a simple heat exchanger used for heat transfer from a temperature difference between two sources. There are many types of heat pipes. An oscillating heat pipe (OHP) is one type. Normally, an OHP is made from a capillary tube. There are three types of OHPs: closed end oscillating heat pipe (CEOHP), closed-loop oscillating heat pipe (CLOHP) and closed-loop oscillating heat pipe with check valves (CLOHP/CV). The OHP has three sections: evaporator, adiabatic and condenser. The oscillating heat pipe with check valve (CLOHP/CV) is widely accepted as the most efficient heat transfer device for high heat loads. It can transfer the heat by itself using the latent heat of the working fluid in the tubes as stated by Akachi et al.[5] and shown in figure 1.

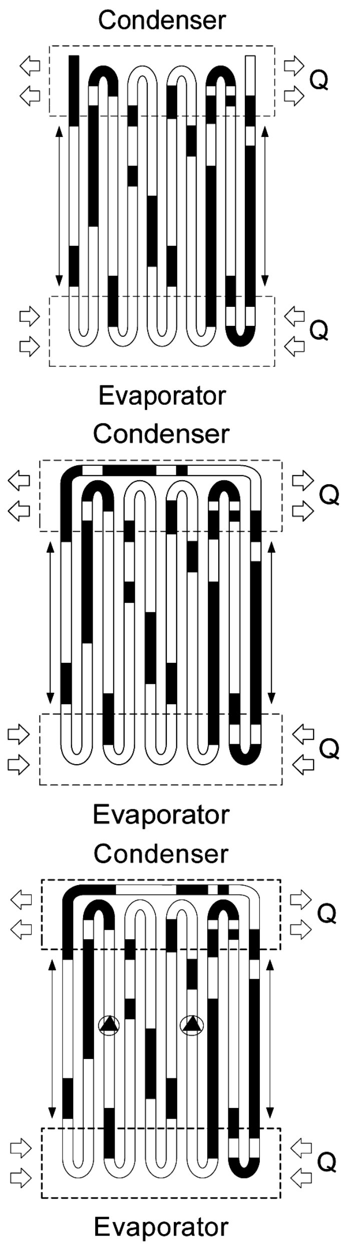

Figure 1 Type of oscillating heat pipe:
(a) Close-end oscillating heat pipe (CEOHP),
(b) Close-loop oscillating heat pipe (CLOHP)and
(c) Close-loop oscillating heat pipe with
Check valves (CLOHP/CV).

Pipatpaiboon et al.[6] studied the effect of inclination angle working fluid and number of check vales on the characteristics of heat transfer in a CLOHP/CV. It was found that the CHOHP/CV equipped with two check valves had the highest heat transfer. In the application of a closed-loop oscillating heat-pipe with check valves (CLOHP/CV), the heat exchanger for the air-preheater is able to use its waste heat in the drying process.

Rittidechet al.[7] studied the heat transfer characteristics of a CLOHP/CV. Rittidech et al.[8] studied the CEOHP air-pre-heater for energy thrift in the dryer. From the experimental results, it was found that thermal effectiveness increases, and the CEOHP air-preheater achieves energy thrift. Meena et al.[9] studied the application of CLOHP/CV for reducing air humidity in the drying process. It was found that a CLOHP/CV can reduce air humidity during these processes. It has been confirmed that the CLOHP/CV heat exchanger is the most efficient heat transfer device. The heat transfers by itself with the latent heat of the working fluid in the tubes. It also serves as a heat exchanger in the dehumidification process of a product by using heat transfer for dehumidification. This research examines the possibility of drying black galingale using biomass working together with a CLOHP/CV heat exchanger.

Experimental setup and procedure

CLOHP/CV heat exchanger

A CLOHP/CV was made from a copper capillary tube with an inner diameter of 5 mm. The ratio of the number of check valves to number of turns was 0.2. The working fluids in this case were water and ethanol with a filling ratio of 50% of total volume of the tube. As shown in figure 2, the length of the evaporator, adiabatic and condenser sections were 20, 5 and 10 cm respectively. Moreover, the CLOHP/CV was set up with a biomass tank as shown in figure 3.

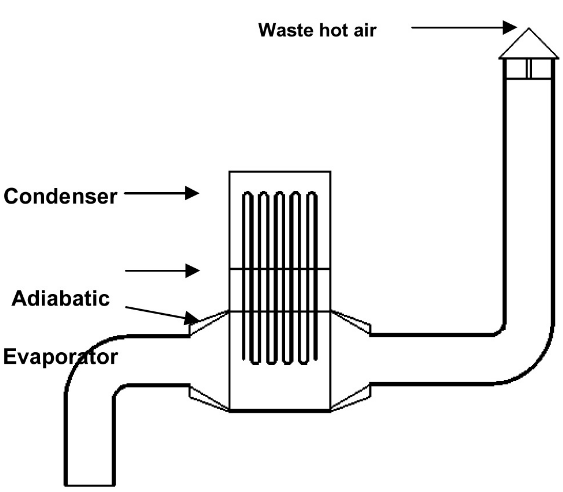

Figure 2 CLOHP/CV part 1 set up of waste hot air pipe from drying chamber.

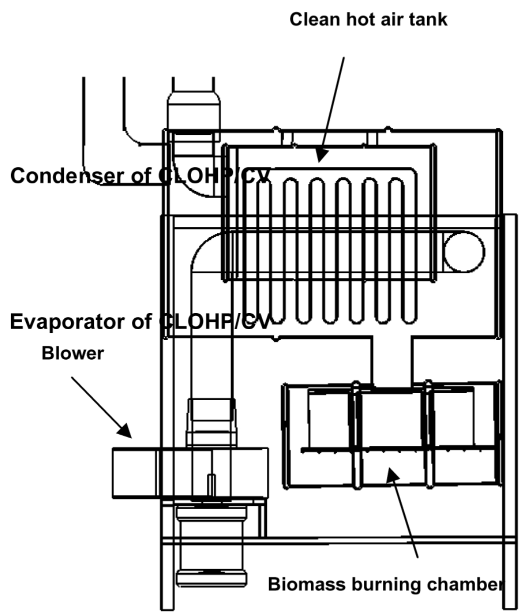

Figure 3 CLOHP/CV part 2 set up of biomass tank.

Drying chamber

The dimensions of the drying chamber were 60 × 100 × 100 cm. The inside of the drying chamber was divided into 4 layers. The distance between each layer was 25 cm and the dimensions of each layer were 53 ´ 57 cm. The waste hot air from the drying process was released at the top of the drying chamber as shown in figure 4.

Figure 4 Drying chamber.

Biomass burning chamber

The biomass burning chamber was made from a 30 liter drum as shown in figure 5. The waste hot air from the biomass burning chamber was passed into a 50 liter tank and the CLOHP/CV was set up for heat transfer. A smaller tank was inserted into the 50 liter tank and the clean hot air for the drying process was product in this part.

Figure 5 Biomass burning chamber.

Black galingale dryer using biomass working together with a CLOHP/CV heat exchanger

The black galingale dryer using biomass working together with a heat exchanger consist of the CLOHP/CV heat exchanger in two parts; the drying chamber and biomass burning chamber as shown in figure 6.

Data analysis

The data was used to calculate the heat transfer of the test CLOHP/CV using the calorific method. The moisture content of the black galingale was measured at the start and end of each run of the hot air oven method using about 10g samples of finely minced black galingale at 103 ˚C for 18 h and dried to a constant weight for 4 h at 125 ˚C. It was found that the initial moisture content was about 143% (wb) to 2.88% (wb). The wet basic moisture content (M_w) was calculated by:

$$M_w = [(w-d)/w] \times 100 \quad (1)$$

Where,

M_w is the wet basic moisture content,
w is the initial weight and
d is the dry product weight.

The effectiveness of the heat exchanger comparing the rate of heat transfer with a heating disposable up of the exchanger of heat can be written as follows:

$$Q = \dot{m} c_p \left(T_{out} - T_{in}\right) \quad (2)$$

$$\varepsilon = \frac{Q_{act}}{Q_{\max}} \quad (3)$$

Where

$$Q_{\max} = C_{\min}(T_{hi} - T_{co}) \quad (4)$$

And

$$Q_{act} = C_o(T_{co} - T_{ci}) \quad (5)$$

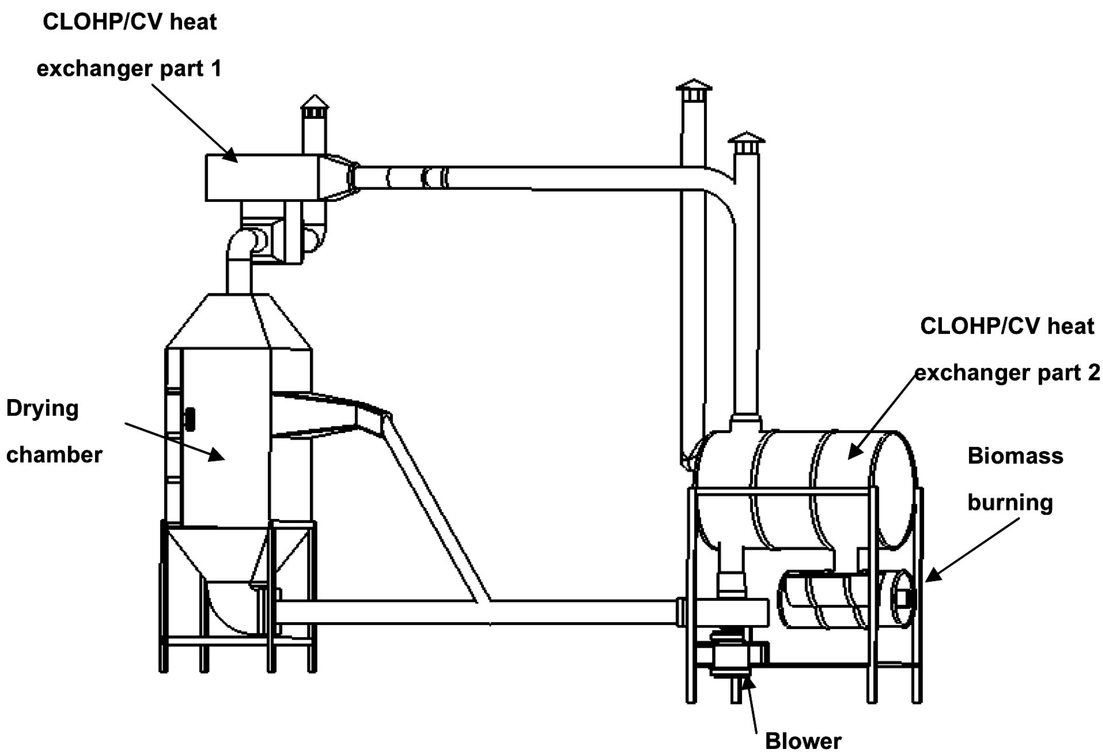

Figure 6 The black galingale dryer by Biomass work together with heat exchanger.

Results and discussion

The air temperature for the experimental period was 60 °C, and the hot air flow rate was 0.5 m/s. The working fluids were water and ethanol. The black galingale was cut into slices of 2 mm thickness.

Figure 7 shows the relation between the moisture content ratios and drying time with different working fluids. It was found that the black galingale drying time process with the CLOGP/CV heat exchanger and ethanol as working fluid was less than the CLOHP/CV heat exchanger with water as the working fluid. The drying time of the CLOHP/CV heat exchanger with ethanol as the working fluid was 6.30 hr and for the CLOHP/CV heat exchanger with water as the working fluid it was 10.30 hrs.

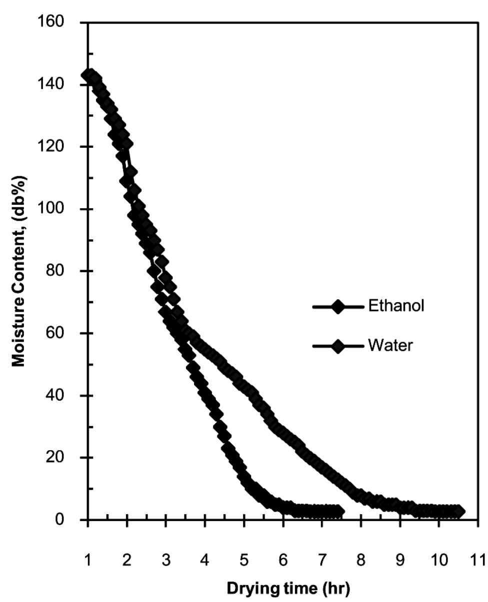

Figure 7 Relationship between moisture content ratio over drying time.

Figure 8 shows the drying rates over drying time. The drying rate using the CLOHP/CV heat exchanger with ethanol as the working fluid was better than using the CLOHP/CV heat exchanger with water as the working fluid.

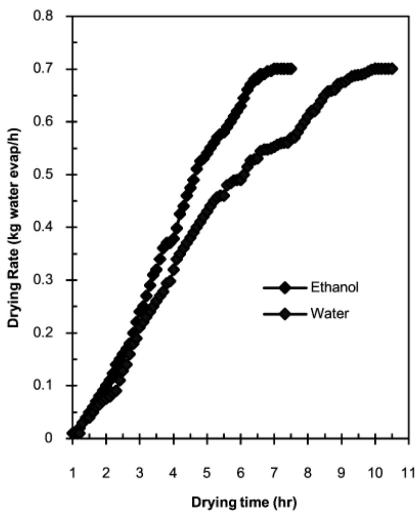

Figure 8 Relationship between the drying rate and time for drying process.

Fig. 9 shows the relationship between the fuel quantities and drying time. It can be seen that the initial drying used a lot of fuel while trying to heat the ambient air to 60 ˚C. It was found that the initial fuel quantity for air heating using the CLOHP/CV heat exchanger with ethanol and water as the working fluids were 3 and 2 kilograms respectively. The overall fuel quantities for the drying process using the CLOHP/CV heat exchanger with ethanol and water as the working fluids were 13.5 and 25 kilograms respectively. The drying time using the CLOHP/CV heat exchanger with ethanol as the working fluid (drying time was 6.30 hrs.) was less than the drying time using the CLOHP/CV heat exchanger with water as the working fluid (drying time 10.30 hrs).

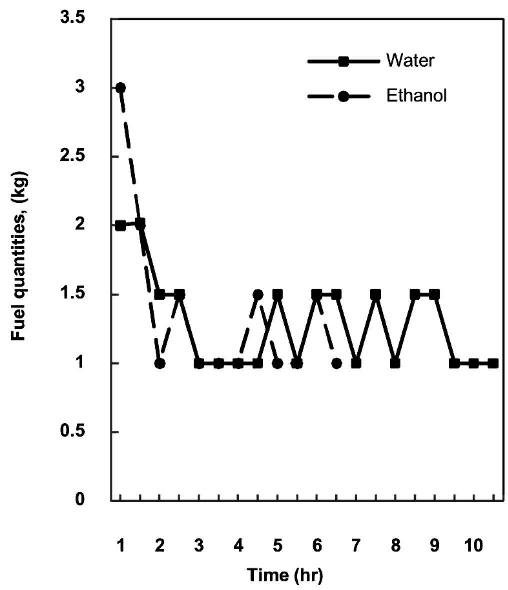

Figure 9 Relationship between fuel quantities and drying time.

Effect of working fluid on heat transfer rate

Figure 10 shows the relationship between the heat transfer rate and the working fluids in the CLOHP/CV. In the CLOHP/CV part 1, it was found that the highest heat transfer rate, when using ethanol as the working fluid in the CLOHP/CV was 1,851.93 watts. In the CLOHP/CV part 2, it was found that the highest heat transfer rate when using ethanol as the working fluid in the CLOHP/CV, was 1,532.84 watt.

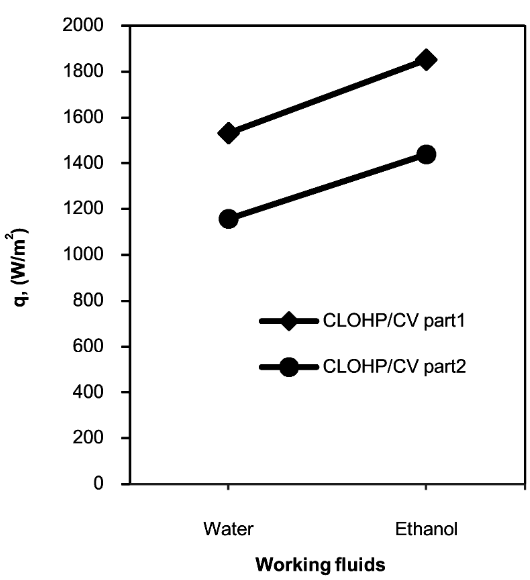

Figure 10 Relationship between heat transfer rate and working fluids in the CLOHP/CV.

Effect of working fluid on effectiveness

Figure 11 shows the relationship between the effectiveness and working fluids in the CLOHP/CV. In the CLOHP/CV part 1, it was found that the highest effectiveness of 0.48 was when ethanol was used as the working fluid in the CLOHP/CV. In the CLOHP/CV part2, it was found that the highest effectiveness of 0.32 was when ethanol was used as the working fluid in the CLOHP/CV.

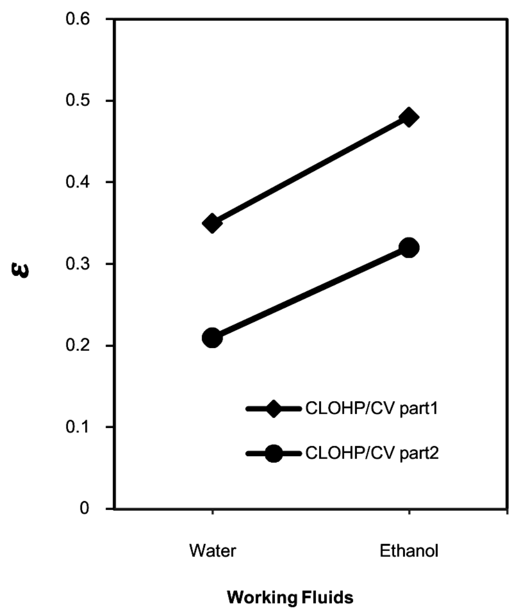

Figure 11 Relationship between effectiveness and working fluids in the CLOHP/CV.

Conclusion

The black galingale dryer using biomass working together with a heat exchanger can save fuel by using a CLOHP/CV as the heat exchanger. The waste hot air from the biomass process was a source of heat for evaporation in the CLOHP/CV. The quality of the fuel for the drying process using the CLOHP/CV heat exchanger with ethanol as the working fluid was better than using the CLOHP/CV heat exchanger with water as the working fluid. Moreover, the drying time using CLOHP/CV heat exchanger with ethanol as the working fluid was less than when using the CLOHP/CV heat exchanger with water as the working fluid.

For the effect of the working fluid on the heat transfer rate and effectiveness, it was found that the CLOHP/CV heat exchanger using ethanol as a working fluid was better than when water was used as the working fluids because the latent heat of the ethanol was the lowest in this experiment. Hence, the moisture content of the black galingale decreased from 143% (db) to 0.28% (db). The fuel quantities, drying time, heat transfer rate and effectiveness, when using ethanol as the working fluid in the CLOHP/CV heat exchanger, were the highest (13.5 kg, 6.30 hrs, 1,851.93 watt and 0.48 respectively). In conclusion, development of a black galingale dryer using biomass working together with a heat exchanger was found to be technically suitable for the drying of black galingale and achieving energy thrift.

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Nomenclature

$\dot{m}$ = Mass per unit time

C_p = Specific heat capacity, constant pressure

T_{out} = Outlet temperature at condenser section

T_{in} = Inlet temperature at condenser section

ε = Effectiveness

Q_{exp} = Experiment heat transfer rate

M_w = Wet basis moisture content

w = initial weight, kg

d = product weight, kg

References

[1] Office of Agricultural Economics Data of agricultural goods in producing and marketing. Ministry of Agriculture and Cooperatives, Bangkok, Thailand, (2007).

[2] Jaishree Prasad; Vijay V.K. Experimental studies on drying of Zingiberofficinale,Curcumalonga I and Tinosporacordifolia in solar-biomass hybrid drier. Renewable Energy, 30, 2097- 2109, (2005).

[3] Mohanraj M; ChandrasekarP ., Drying of copra in a forced convection solar drier.Biosystems Engineering, 99, 604 – 607.(2008).

[4] Hossain M.A; Bala B.K., Drying of hot chilli using solar tunnel drier. Solar Energy, 81, 85–92.(2007).

[5] Akachi H; Polasek F; Stulc P., Pulsating heat pipe. Proceeding of the 5th international Heat pipe symposium, Melbourne Australia, 208-217.(1996).

[6] Pipatpaiboon N; Rittidech S; Sukna T; SuddeeP., Effect of inclination angleworking fluid and number of check valveson the characteristics of heat transfer in aclosed-looped oscillating heat-pipe with check valves (CLOHP/CV). Proceeding of 1st international seminar on heat pipe and heatrecovery systems, Kuala Lumpur, Malaysia, 83- 87. (2004).

[7] Rittidech S; Pipatpaiboon N; Terdtoon P., Heat-transfer characteristics of a closed-looped oscillating heat pipe with check valves. Applied Energy, 84, 565-577.(2007).

[8] Rittidech S; Dangeton W; SoponronnaritS .,Closed-ended oscillating heat-pipe (CEOHP) air-preheater for energy thrift in dryer. Applied Energy, 81, 198-208.(2005).

[9] Meena P; Rittidech S; andPoomsaN.,Application of Close-looped oscillating heat-pipe with check valves (CLOHP/CVs) air-preheater for reduced relative-humidity in drying systems. Applied Energy, 84, 553-564.(2007).