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BIOGAZ-ISSIQLIK QUVURLI QURILMA REAKTORINING ISSIQLIK REJIMINI TADQIQOT QILISH

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Annotatsiya: *Maqolada biogaz-issiqlik quvurli qurilma reaktorining issiqlik balansi tuzilgan. Ushbu balans tenglamasi asosida havo va biomassa harorati o'zgarishini matematik modeli keltirilgan. Biogaz-issiqlik quvurli qurilmaning tiniq yuzasidan o'tgan quyosh energiyasi hisobidan havoning haroratini 80-85℃ gacha qizdirishi hamda qurilma ichidagi biomassa ham qizishi natijasida anaerobik bijg'ish jarayoni davom etishi aniqlangan. Ushbu issiqlikni issiqlik quvuri ichidagi issiqlik tashuvchi orqali issiqhonaga uzatish va issiqxonaning harorat rejimini ta'minlash imkoniyatini berishi tajriba natijalari asosida isbotlangan. Natijada, biogaz-issiqlik quvurli qurilma issiqxonani isitish mavsumida issiqlik yuklamasini to'liq qoplashi mumkindigi asoslangan. Modellashtirish natijalari bilan o'tkazilgan eksperimental tadqiqot natijalari 4-6% farq qilishi grafiklarda yoritilgan.*

Kalit so'zlar: *biogaz-issiqlik quvurli qurilma, bioreaktor, anaerobik bijg'ish jarayoni, issiqlik tashuvchi, issiqlik balansi tenglamasi.*

ИССЛЕДОВАНИЕ ТЕПЛОВОГО РЕЖИМА БИОГАЗОТРУБЧАТОГО РЕАКТОРА

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Аннотация: *В статье составлен тепловой баланс реактора биогазотрубного устройства. На основе уравнения баланса представлена математическая модель изменения температуры воздуха и биомассы. Установлено, что тепловая энергия, проходящая через чистую поверхность биогазотрубного устройства, нагревает температуру воздуха до 80-85℃, а в результате нагревания биомассы внутри устройства продолжается процесс анаэробного брожения. На основании экспериментальных результатов доказано, что это тепло может передаваться в теплицу через теплоноситель внутри тепловой трубы и обеспечивать температурный режим теплицы. В результате установлено, что биогазо-теплотрубное устройство может полностью покрыть тепловую нагрузку в течение отопительного сезона теплицы. На графиках показаны результаты экспериментального исследования отличаюсушся на 4-6% от результатов моделирования.*

Ключевые слова: *биогазотрубное устройство, биореактор, процесс анаэробного сбраживания, теплоноситель, уравнение теплового баланса.*

INVESTIGATING THE THERMAL REGIME OF THE BIOGAS-HEAT PIPE REACTOR

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Abstract: *the heat balance of the reactor of the biogas-heat pipe device is compiled in the article. Based on this balance equation, a mathematical model of air and biomass temperature change is presented. It has been determined that the temperature of the heated air due to solar energy passing through the clear surface of the biogas-heat pipe device is heated up to 85-95℃, and as a result of the heating of the biomass inside the device, the process of anaerobic fermentation continues. It has been proven on the basis of experimental results that this heat can be transferred to the greenhouse through the heat carrier inside the heat pipe and provide the temperature regime of the greenhouse. As a result, it is based on the fact that the biogas-heat pipe device can fully cover the heat load during the heating season of the greenhouse. It is shown in the graphs that the results of the experimental study differ by 4-6% from the results of modeling.*

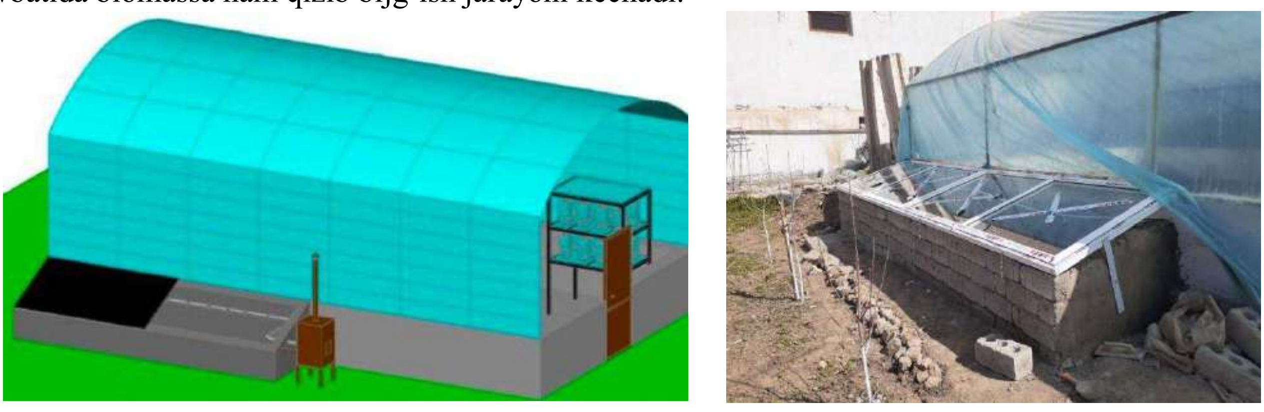
Keywords: *biogas-heat pipe device, bioreactor, anaerobic digestion process, heat carrier, heat balance equation.*

Hozirgi vaqtda an'anaviy yoqilg'ining cheklangan zaxiralarining kamayib borishi natijasida elektr va issiqlik uchun tariflarning doimiy oshishi muqobil energiya manbalariga bo'lgan ehtiyojni ortishiga olib kelmoqda. Qishloq xo'jaligi ishlab chiqarishining istiqbolli yo'nalishi - biotexnologiya orqali energiya ishlab chiqarishdir. O'zbekiston Respublikasi Prezidentining 2018-yil 20-noyabrdagi "Issiqxona komplekslarini rivojlantirish uchun qo'shimcha shart-sharoitlar yaratish chora-tadbirlari to'g'risida"gi PQ-4020-sonli qarorida issiqxona xo'jaliklarini yuritishda qayta tiklanuvchi energiya manbalaridan foydalanishni rivojlantirish ustuvor vazifa sifatida belgilab berilgan.

Qishloq xo'jaligini mahsulotlarini etishtirish va ularni saqlashda qayta tiklanuvchi energiya manbalari xususan, quyosh energiyasidan samarali foydalanish bo'yicha nazariy-amaliy tadqiqot ishlari olib borilmoqda. Shuning uchun quyosh issiqxonalarni takomillashtirish va tejamkor ishlashini ta'minlash muhim ahamiyatga egadir.

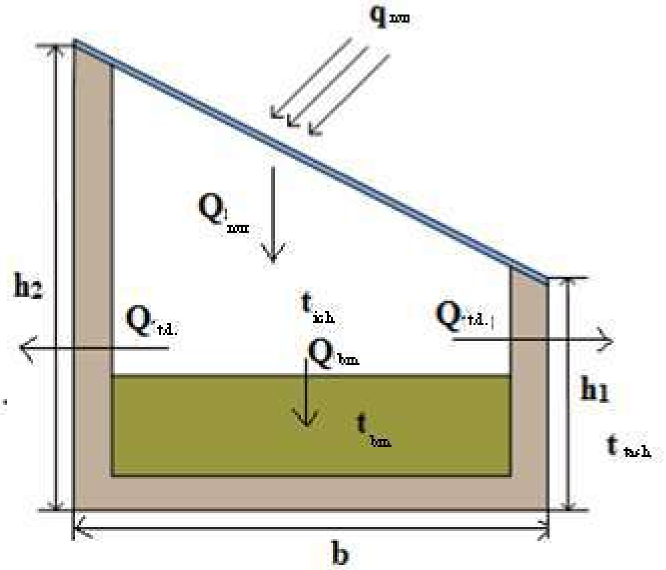
Ilmiy-tadqiqot natijalari shuni ko'rsatadiki, issiqxonaning devorlar orqali umumiy yo'qotiladigan issiqlik miqdori 10-15% ni, derazalar orqali 20-25% ni, pol va shift yopilmalari orqali esa 10-15% ni kirish va chiqish eshiklari orqali 5-8% ni tashkil etadi [1-5]. Issiqxonada quyoshning nuridan tushayotgan issiqlikni ushlab qolish natijasida issiqlik saqlovchi materiallarni qo'llash va ulardan foydalanish 10-20% energiya tejash imkonini beradi.

Issiqxonalarning issiqlik ta'minoti uzluksizligini ta'minlashda biogaz-issiqlik quvurli reaktor qurilmasini ishlab chiqish orqali yil davomida issiqxonaning issiqlik energiyasiga bo'lgan ehtiyojini qoplash mumkin (1-rasm). Ushbu qurilma issiqxona devori bilan yonma-yon qurilgan bo'lib, qurilmaning tiniq yuzasiga kun davomida quyosh energiyasi tushib, ichidagi havoni va biomassani qizdiradi. Devorida o'rnatilgan issiqlik quvurining bir uchiga havo tomonidan issiqliq berilib, issiqxona tuprog'i ostida joylashgan ikkinchi uchiga issiqlik tashuvchi (freon) orqali uzatiladi. O'z navbatida biomassa ham qizib bijg'ish jarayoni kechadi.



1-rasm. Issiqlik quvurli qurilmaning tajriba namunasi.

Biogaz-issiqlik quvurli qurilma reaktorining issiqlik rejimini matematik modellashtirishda havo va biomassani fizik parametrlarini harorat bo‘yicha o‘zgarishini hisobga olmagan holda 2-rasmdagi hisob sxema asosida issiqlik balansini tuzamiz [6].



2-rasm. Biogaz-issiqlik quvurli qurilma reaktorining issiqlik rejimini hisob sxemasi.

Kameraning havosi va biomassa uchun issiqlik balansini quyidagicha ifodalash mumkin:

$$Q_{is.h} = Q_{nur} - Q_{t.d.} - Q_{bm};$$
$$Q_{bm} = \rho_{bm} \cdot V_{bm} \cdot c_{bm} \frac{dt_{bm}(\tau)}{d\tau}. \quad (1)$$

bu erda: $Q_{t.d.}$ - devor orqali issiqlik yo‘qotilishi, Vt; Q_{nur} - quyosh nurlanishi orqali o‘tgan issiqlik, Vt; Q_{bm} - biomassani qizdirishga sarflanadigan issiqlik, Vt.

Devor orqali issiqlik yo‘qotilishi. Devorning qalinligi $\delta_{dev.} = 0,25m$, issiqlik o‘tkazuvchanlik koeffitsyienti $\lambda_{g'isht} = 0,56 \dfrac{Vt}{\left(m\,^0c\right)}$. Qurilmaning uzunligi $a = 2,5\,m$, eni $b = 1,2\,m$, balandligi $h_1 = 1,4\,m,\ h_2 = 1\,m$; shtukaturkaning issiqlik o‘tkazuvchanlik koeffitsyienti $\lambda_{um.} = 0,93 \dfrac{Vt}{m\,^0C}$; qalinligi $\delta_{sht.} = 0,015m$.

Tashqi devorning yuzasi $F_{t.d.} = (a+b)\cdot(h_1+h_2) = (2,5+1,2)(1,4+1) = 8,9\,m^2$; ifoda orqali hisoblanadi. Tashqi devorning termik qarshiligi quyidagi formuladan aniqlanadi:

$$R_{t.d.} = R_{ich.} + \sum_{i=1}^{m} R_{ri} + R_{tash.}$$

bu erda: $R_{ich.} = 1/\alpha_{ich.} = 0,115\ (m^2 \cdot {}^0 C)/Vt$ - ichki devorning issiqlik qarshiligi; $R_{ri} = \dfrac{\delta_i}{\lambda_i}$ - m - qatlamli to‘siqning alohida qatlamlarining termik qarshiligi, $(m^2 \cdot {}^0 C)/Vt$; $R_{tash.} = 1/\alpha_{tash.} = 0,043 (m^2 \cdot {}^0 C)/Vt$ - tashqi devorning issiqlik qarshiligi.

Tashqi devorning issiqlik uzatish qarshiligi:

$$R_{t.d.} = 0,115 + 2 \cdot \frac{0,015}{0,93} + \frac{0,25}{0,56} + 0,043 = 0,64 (m^2 \cdot {}^0 C)/Vt$$

Kameraning tom qismida o‘rnatilgan oynaning termik qarshiligi $R_{t.o.} = 0,345(m^2 \cdot {}^0C)/Vt$, yuzasi $F_{oy} = a \cdot \sqrt{b^2 + (h_1 - h_2)^2} = 2,5 \cdot \sqrt{1,2^2 + (1,4-1)^2} = 3,162\,m^2 \approx 3\,m^2$; Tashqi devor va oyna orqali issiqlik yo‘qotilishi quyidagi formuladan aniqlanadi [4]

$$Q_{t.d.} = \frac{F_{t.d.}}{R_{t.d.}}(t_{ich}(\tau) - t_{tash.}) + \frac{F_{oy}}{R_{t.o.}}(t_{ich}(\tau) - t_{tash.}) = (\frac{F_{t.d.}}{R_{t.d.}} + \frac{F_{oy}}{R_{t.o.}}) \cdot (t_{ich}(\tau) - t_{tash.}) = = (\frac{8,9}{0,64} + \frac{3}{0,345}) \cdot (t_{ich}(\tau) - t_{tash.}) = 22,6 \cdot (t_{ich}(\tau) - t_{tash.}) \quad (2)$$

Quyosh nurlanishi. Kamera tom qismida o‘rnatilgan tiniq yuzadan (oyna) o‘tadigan quyosh nurlanishi quyidagi ifoda yordamida topiladi [7].

$$Q_{nur} = q_{nur} \cdot \alpha_p \cdot \kappa_{prop.} \cdot F_{oy} \quad (3)$$

bu erda q_{nur} - yuza birligiga tushadigan quyosh nurlanishining intensivligi, Vt/m^2; $\alpha_p = 0,8$, $\kappa_{prop.} = 0,9$;

Biomassani qizdirishga sarflanadigan issiqlik. Kameradagi biomassani xajmi umumiy xajmning 1/3 qismiga teng deb qaraymiz, ya’ni:

$V_{bm} = \frac{a \cdot b \cdot (h_1 + h_2)}{2} \cdot \frac{1}{3} = \frac{2,5 \cdot 1,2 \cdot (1,4+1)}{2} \cdot \frac{1}{3} = 1,2\,m^3$. Biomassaning zichligi $\rho_{bm} = 1016,5\; kg/m^3$; Solishtirma issiqlik sig‘imi $c_{bm} = 4180\,J/(kg \cdot {}^0C)$ [8]: .

Biomassani qizdirishga sarflanadigan issiqlikni quyidagicha yozish mumkin [9]:

$$Q_{bm} = \alpha_h \cdot F_{bm}(t_{ich}(\tau) - t_{bm}(\tau)) \quad (4)$$

bu erda: α_h - havodan biomassaga beriladigan issiqlik berish koeffitsienti bo‘lib, $\alpha_h = 30\,Vt/(m^2 \cdot {}^0C)$ qabul qilamiz; $F_{bm} = a \cdot b = 1,2 \cdot 2,5 = 3\,m^2$ - biomassa erkin sirti yuzasi; $t_{бм}$ - biomassa harorati, °C;

(2), (3), (4) ifodalarni e’tiborga olib (1) ifodani quyidagicha yozish mumkin:

$$\rho_h \cdot V_h \cdot c_h \frac{dt_{ich}(\tau)}{d\tau} = q_{nur} \cdot \alpha_p \cdot \kappa_{prop.} \cdot F_{oy} - (\frac{F_{t.d.}}{R_{t.d.}} + \frac{F_{oy}}{R_{t.o.}}) \cdot (t_{ich}(\tau) - t_{tash.}) - \alpha_h \cdot F_{bm}(t_{ich}(\tau) - t_{bm}(\tau));$$
$$\rho_{bm} \cdot V_{bm} \cdot c_{bm} \frac{dt_{bm}(\tau)}{d\tau} = \alpha_h \cdot F_{bm}(t_{ich}(\tau) - t_{bm}(\tau)) \quad , (5)$$

bu erda: ρ_h, c_h - mos ravishda havoning zichligi va solishtirma issiqlik sig‘imi; V_x - kameraning hajmi bo‘lib, kamera hajmining 2/3 qismiga teng ya’ni, $V_h = \frac{a \cdot b \cdot (h_1 + h_2)}{2} \cdot \frac{2}{3} = \frac{2,5 \cdot 1,2 \cdot (1,4+1)}{2} \cdot \frac{2}{3} = 2,4\,m^3$.

(5) tenglamalarni birinchi tartibli chiziqli differensial tenglamalar ko‘rinishida ifodalaymiz:

$$\begin{cases} \frac{dt_{ich}(\tau)}{d\tau} = -\frac{(\frac{F_{t.d.}}{R_{t.d.}} + \frac{F_{oy}}{R_{t.o.}}) + \alpha_h \cdot F_{bm}}{\rho_h \cdot V_h \cdot c_h} t_{ich.}(\tau) + \frac{\alpha_h \cdot F_{bm}}{\rho_h \cdot V_h \cdot c_h} t_{bm}(\tau) + \frac{q_{nur} \cdot \alpha_p \cdot \kappa_{prop.} \cdot F_{oy} + (\frac{F_{t.d.}}{R_{t.d.}} + \frac{F_{oy}}{R_{t.o.}}) \cdot t_{tash.}}{\rho_h \cdot V_h \cdot c_h}; \\ \frac{dt_{bm}(\tau)}{d\tau} = -\frac{\alpha_h \cdot F_{bm}}{\rho_{bm} \cdot V_{bm} \cdot c_{bm}} t_{bm}(\tau) + \frac{\alpha_h \cdot F_{bm}}{\rho_{bm} \cdot V_{bm} \cdot c_{bm}} t_{ich}(\tau). \end{cases} \quad (6)$$

(6) tenglamalar sistemasini ikkinchi bandi echimini quyidagicha yozamiz [10]:

$$t_{bm}(\tau) = C \cdot e^{-\frac{\alpha_h \cdot F_{bm}}{\rho_{bm} \cdot V_{bm} \cdot c_{bm}}\tau} + t_{ich}(\tau) \quad (7)$$

bu erda C o‘zgarmas son bo‘lib, $\tau=0,\ t_{bm}(0)=t_{bm0},\ t_{ich}(0)=t_{tash}$ shart asosida $C=t_{bm0}-t_{tash}$ ekanligidan (7) ifodani quyidagicha ifodalaymiz:

$$t_{bm}(\tau)=(t_{bm0}-t_{tash})\cdot e^{-\frac{\alpha_h\cdot F_{bm}}{\rho_{bm}\cdot V_{bm}\cdot c_{bm}}\tau}+t_{ich}(\tau) \quad (8)$$

(8) ifodani (6) tenglamalar sistemasini birinchi bandiga qo‘yib, quyidagini hosil qilamiz:

$$\frac{dt_{ich}(\tau)}{d\tau}=-\frac{(\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}})}{\rho_x\cdot V_x\cdot c_x}t_{ich.}(\tau)+$$

$$+\frac{\alpha_h\cdot F_{bm}\cdot e^{-\frac{\alpha_h\cdot F_{bm}}{\rho_{bm}\cdot V_{bm}\cdot c_{bm}}\tau}\cdot t_{bm0}+(\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}}-\alpha_h\cdot F_{bm}\cdot e^{-\frac{\alpha_h\cdot F_{bm}}{\rho_{bm}\cdot V_{bm}\cdot c_{bm}}\tau})\cdot t_{tash}+q_{nur}\cdot\alpha_p\cdot\kappa_{prop.}\cdot F_{oy}}{\rho_h\cdot V_h\cdot c_h} \quad (9)$$

(9) differensial tenglama echimini quyidagicha yozish mumkin:

$$t_{ich}(\tau)=C\cdot\exp(-\frac{(\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}})}{\rho_h\cdot V_h\cdot c_h}\tau)+$$

$$+\frac{\alpha_h\cdot F_{bm}\cdot e^{-\frac{\alpha_h\cdot F_{bm}}{\rho_{bm}\cdot V_{bm}\cdot c_{bm}}\tau}\cdot t_{bm0}+(\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}}-\alpha_h\cdot F_{bm}\cdot e^{-\frac{\alpha_h\cdot F_{bm}}{\rho_{bm}\cdot V_{bm}\cdot c_{bm}}\tau})\cdot t_{tash}+q_{nur}\cdot\alpha_p\cdot\kappa_{prop.}\cdot F_{oy}}{\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}}} \quad (10)$$

bu erda C o‘zgarmas son bo‘lib, $\tau=0,\ t_{ich}(0)=t_{tash}$ shart asosida

$$C=t_{tash}-\frac{\alpha_h\cdot F_{bm}\cdot t_{bm0}+(\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}}-\alpha_h\cdot F_{bm})\cdot t_{tash}+q_{nur}\cdot\alpha_p\cdot\kappa_{prop.}\cdot F_{oy}}{\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}}}$$

ekanligidan (10) ifodani quyidagicha ifodalaymiz:

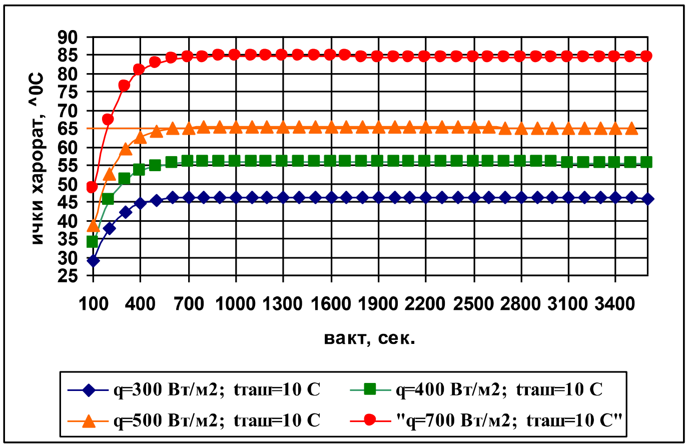
$$t_{ich}(\tau)=t_{tash}+\frac{\alpha_h\cdot F_{bm}}{\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}}}(\exp(-\frac{\alpha_h\cdot F_{bm}}{\rho_{bm}\cdot V_{bm}\cdot c_{bm}}\tau)-\exp(-\frac{(\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}})}{\rho_h\cdot V_h\cdot c_h}\tau))\cdot(t_{bm0}-t_{tash})+$$

$$+\frac{q_{nur}\cdot\alpha_p\cdot\kappa_{prop.}\cdot F_{oy}}{\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}}}\cdot(1-\exp(-\frac{(\frac{F_{t.d.}}{R_{t.d.}}+\frac{F_{oy}}{R_{t.o.}})}{\rho_h\cdot V_h\cdot c_h}\tau)) \quad (11)$$

(11) ifodadagi kattaliklar qiymatini 1-jadvalda va shu asosida statsionar holatdagi ichki havo haroratining vaqt bo‘yicha o‘zgarishini hisoblab 3-rasmda ifodalaymiz.

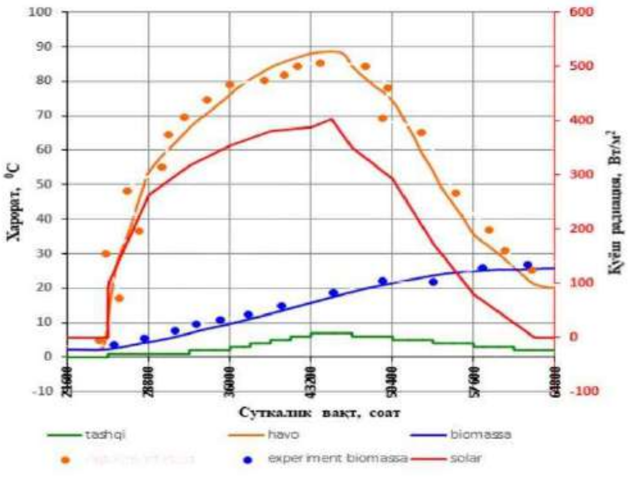
1-jadval

№	Parametrlar	Belgilanishi	O‘lchov birligi	Qiymati
1	Havo hajmi, m^3	V_h	m^3	2,4
2	Havoning solishtirma issiqlik sig‘imi	c_h	$J/(кg\cdot^0 C)$	1005
3	Havoning zichligi	ρ_h	$кg/m^3$	1,29
4	Biomassa hajmi, m^3	V_{bm}	m^3	1,2
5	Biomassaning solishtirma issiqlik sig‘imi	c_{bm}	$J/(кg\cdot^0 C)$	3500
6	Biomassa zichligi	ρ_{bm}	$кg/m^3$	1016,5
7	Biomassa erkin sirti	F_{bm}	m^2	3
8	Biomassani boshlang‘ich harorati	t_{bm0}	^0C	12
9	Tashqi havo harorati	t_{tash}	^0C	10



3-rasm. Biogaz-issiqlik quvurli qurilma reaktori ichidagi havo haroratining vaqt bo‘yicha statsionar holatdagi o‘zgarishi.

Qurilma tiniq yuzasiga tushadigan yig‘indi quyosh radiatsiyasi va tashqi havo haroratini sutkalik o‘zgarishini (07.12.2021-y.) Qarshi shahri uchun GlogalSolarMap tizimidan olingan qiymatlari asosida nostatsionar holatdagi haroratning vaqt bo‘yicha o‘zgarishini 4-rasmda ifodalaymiz.



4-rasm. Biogaz-issiqlik quvurli qurilma reaktori ichidagi havo va biomassa haroratini nostatsionar holatdagi sutkalik o‘zgarishi (07.12.2021-y.).

Biogaz-issiqlik quvurli qurilmaning harorat rejimini matematik modelini yechimidan quyidagicha xulosalar qilish mumkin:

- tashqi harorati 10 °C bo‘lganda qurilma tiniq yuzasiga tushadigan yig‘indi quyosh radiatsiyasiga mos holda ichki havo haroratini 85-90 °Cgacha qizdirish mumkin;
- qizigan havoning ichki energiyasi yordamida biomassa haroratini oshirishga va issiqlik quvuri ichidagi issiqlik tashuvchi orqali issiqhona yuklamasini qisman qoplashga erishiladi;
- sutka davomida biomassa harorati 25 °C gacha ko‘tariladi;
- qurilma ichidagi biomassa qizishi natijasida anaerobik usulda olingan biogazni suv qizdirish qozonida yonishi hisobidan qizigan suv yordamida issiqhona issiqlik yuklamasi to‘liq qoplanadi.

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